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Contribution	LBNE Collaborator(s)
<i>Overall editing</i>	<i>Anne Heavey, Mary Bishai, Jon Urheim, Brett Viren, Maury Goodman</i>
<i>Technical/Figures</i>	Brett Viren
<i>Original content</i>	<i>Bob Wilson (Editor of the 2010 Interim Physics Report)</i>
<i>General Guidance</i>	Milind Diwan, Bob Wilson, Jim Strait, Sam Zeller, Bill Louis, Hank Sobel, Josh Klein, Nick Samios

Major Contributors by Chapter. A * indicates the chapter editor(s)

<i>exec-sum-chap</i> Chapter 1	Jon Urheim*, Jim Strait, Bob Wilson
<i>intro-chap</i> Chapter 2	Mary Bishai*, Elizabeth Worcester*, Jon Urheim, Kate Scholberg, Ed Kearns, Bill Marciano, Xin Qian.
<i>project-chap</i> Chapter 3	Mary Bishai*, Jim Strait, Elaine McCluskey, Kevin Lesko, Jim Stewart, Vaia Papadimitriou, Kevin Yarritu, Bill Louis
<i>nu-oscil-chap</i> Chapter 4	Elizabeth Worcester*, Mary Bishai*, Matt Bass, Andy Blake, Xin Qian, Jon Urheim, Lisa Whitehead
<i>pdk-chap</i> Chapter 5	Ed Kearns*, Jon Urheim*, Vitaly Kudryavtsev
<i>sn-chap</i> Chapter 6	Kate Scholberg*, Vic Gehman, Alex Friedland
<i>nd-physics-chap</i> Chapter 7	Roberto Petti*, Sanjib Mishra, Jaehoon Yu, Richard Van de Water
<i>chap-other-goals</i> Chapter 8	Michael Smy*, Mary Bishai*, Jaehoon Yu
<i>conclusion-chap</i> Chapter 9	Jon Urheim*, Jim Strait
<i>app-sim</i> Appendix A	Dan Cherdack*, Tom Junk*, Andy Blake, Vitaly Kudryavtsev, Zepeng Li, Kate Scholberg
<i>app-dis</i> Appendix B	Mary Bishai*, Roberto Petti

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REFERENCES

- 27 1. “APS Division of Particles and Fields Community Summer Study 2013,” 2013.
 28 <http://www.snowmass2013.org>. Cited in Sections 1.1 (pg.4), 1.2.1 (pg.6),
 29 and B (pg.235).
- 30 2. M. Diwan and C. Jung, “Next generation nucleon decay and neutrino detector.
 31 Proceedings, Workshop, NNN99, Stony Brook, USA, September 23-25, 1999,” 2000.
 32 Cited in Section 1.2 (pg.5).
- 33 3. W. J. Marciano, “Extra long baseline neutrino oscillations and CP violation,”
 34 BNL-HET-01-31, arXiv:hep-ph/0108181 [hep-ph], 2001. Cited in Section 1.2 (pg.5).
- 35 4. R. Shrock, “Neutrinos and implications for physics beyond the standard model.
 36 Proceedings, Conference, Stony Brook, USA, October 11-13, 2002,” 2003. Cited in
 37 Section 1.2 (pg.5).
- 38 5. M. Diwan, W. Marciano, W. Weng, D. Beavis, M. Brennan, *et al.*, “Report of the BNL
 39 neutrino working group: Very long baseline neutrino oscillation experiment for precise
 determination of oscillation parameters and search for $\nu\mu \rightarrow \nu e$ appearance and CP

- 41 violation," BNL-69395, arXiv:hep-ex/0211001 [hep-ex], 2002. Cited in
1 Section 1.2 (pg.5).
- 2 6. M. Diwan, D. Beavis, M.-C. Chen, J. Gallardo, S. Kahn, *et al.*, "Very long baseline
3 neutrino oscillation experiments for precise measurements of mixing parameters and CP
4 violating effects," *Phys.Rev.* **D68** (2003) 012002, arXiv:hep-ph/0303081 [hep-ph].
5 Cited in Section 1.2 (pg.5).
- 6 7. W. Weng, M. Diwan, D. Raparia, J. Alessi, D. Barton, *et al.*, "The AGS-Based Super
7 Neutrino Beam Facility Conceptual Design Report," BNL-73210-2004-IR, 2004. Cited in
8 Section 1.2 (pg.5).
- 9 8. M. Diwan, S. H. Kettell, L. Littenberg, W. Marciano, Z. Parsa, *et al.*, "Proposal for an
10 Experimental Program in Neutrino Physics and Proton Decay in the Homestake
11 Laboratory," BNL-76798-2006-IR, arXiv:hep-ex/0608023 [hep-ex], 2006. Cited in
12 Section 1.2 (pg.5).
- 13 9. V. Barger, M. Bishai, D. Bogert, C. Bromberg, A. Curioni, *et al.*, "Report of the US long
14 baseline neutrino experiment study," FERMILAB-0801-AD-E, BNL-77973-2007-IR,
15 arXiv:0705.4396 [hep-ph], 2007. Cited in Section 1.2 (pg.5).
- 16 10. N. R. C. Neutrino Facilities Assessment Committee, *Neutrinos and Beyond: New Windows
17 on Nature*. The National Academies Press, 2003. ISBN 0-309-08716-3. Cited in
18 Section 1.2 (pg.5).
- 19 11. Interagency Working Group on the Physics of the Universe. National Science and
20 Technology Council Committee on Science, "A 21st Century Frontier of Discovery: The
21 Physics of the Universe, a Strategic Plan for Federal Research at the Intersection of Physics
22 and Astronomy.". February, 2004.
23 http://pcos.gsfc.nasa.gov/docs/Physics_of_the_Universe.pdf. Cited in
24 Section 1.2 (pg.5).
- 25 12. N. R. C. Committee on Elementary Particle Physics in the 21st Century, *Revealing the
26 Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics*.
27 The National Academies Press, 2006. ISBN 0-309-66039-4. Cited in Section 1.2 (pg.5).
- 28 13. Neutrino Scientific Assessment Group, "Recommendations to the Department of Energy
29 and the National Science Foundation on a Future U.S. Program in Neutrino Oscillations.
1 Report to the Nuclear Science Advisory Committee and the High Energy Physics Advisory
2 Board.". July, 2007. http://science.energy.gov/~/media/hep/pdf/files/pdfs/nusagfinalreportjuly13_2007.pdf. Cited in Section 1.2 (pg.5).
- 4 14. Particle Physics Project Prioritization Panel, "U.S. Particle Physics: Scientific
5 opportunities, a plan for the next ten years.". May, 2008. http://science.energy.gov/~/media/hep/pdf/files/pdfs/p5_report_06022008.pdf.
6 Cited in Sections 1.2 (pg.5), 3.1 (pg.46), and 3.2 (pg.48).
- 8 15. Ad Hoc Committee to Assess the Science Proposed for a Deep Underground Science and
9 Engineering Laboratory (DUSEL); National Research Council, *An Assessment of the Deep
10 Underground Science and Engineering Laboratory*. The National Academies Press, 2012.
11 ISBN 978-0-309-21723-1. Cited in Section 1.2 (pg.5).

16. HEPAP Facilities Subpanel, “Major High Energy Physics Facilities 2014-2024. Input to the
17 prioritization of proposed scientific user facilities for the Office of Science.”. March, 2013.
18 http://science.energy.gov/~media/hep/hepap/pdf/Reports/HEPAP_facilities_letter_report.pdf. Cited in Section 1.2 (pg.5).
19. CERN Council, “The European Strategy for Particle Physics, Update 2013.”.
20 CERN-Council-S/106, May, 2013.
21 <http://council.web.cern.ch/council/en/EuropeanStrategy/esc-e-106.pdf>.
22 Cited in Sections 1.2 (pg.5) and 1.2.3 (pg.7).
23. DOE Office of Science, Office of High Energy Physics, “Mission Need Statement for a
24 Long-Baseline Neutrino Experiment (LBNE),” DOE, LBNE-doc-6259, 2009. Cited in
25 Sections 1.2.1 (pg.6) and 3.1 (pg.47).
26. A. S. Kronfeld, R. S. Tschirhart, U. Al-Binni, W. Altmannshofer, C. Ankenbrandt, *et al.*,
27 “Project X: Physics Opportunities,” FERMILAB-TM-2557, BNL-101116-2013-BC-81834,
28 JLAB-ACP-13-1725, UASLP-IF-13-001, SLAC-R-1029, ANL-PHY-13-2, PNNL-22523,
29 LBNL-6334E, arXiv:1306.5009 [hep-ex], 2013. Cited in Section 1.2.1 (pg.6).
30. A. de Gouvea *et al.*, **Intensity Frontier Neutrino Working Group**, “Neutrinos,”
31 FERMILAB-CONF-13-479-E, arXiv:1310.4340 [hep-ex], 2013. Cited in
32 Sections 1.2.1 (pg.6) and 2.2 (pg.23).
33. K. Babu, E. Kearns, U. Al-Binni, S. Banerjee, D. Baxter, *et al.*, “Baryon Number
34 Violation,” arXiv:1311.5285 [hep-ph], 2013. Cited in Section 1.2.1 (pg.6).
35. Derwent, P. and others, “Proton Improvement Plan II,” Project X-doc-1232, November,
36 2013. Cited in Sections 1.2.1 (pg.6), 3.2 (pg.51), and 3.4 (pg.63).
37. S. Holmes, R. Alber, B. Chase, K. Gollwitzer, D. Johnson, *et al.*, “Project X: Accelerator
38 Reference Design,” FERMILAB-TM-2557, BNL-101116-2013-BC-81834,
39 JLAB-ACP-13-1725, PNNL-22523, SLAC-R-1020, UASLP-IF-13-001,
40 arXiv:1306.5022 [physics.acc-ph], 2013. Cited in Sections 1.2.1 (pg.6),
41 3.2 (pg.51), and 4.2.1 (pg.88).
42. “Final Report, Director’s Independent Conceptual Design and CD-1 Readiness Review of
43 the LBNE Project,” LBNE-doc-5788, March, 2012. Cited in Sections 1.2.2 (pg.7),
44 3.6 (pg.76), and 3.6.2 (pg.79).
45. Y. K. Kim *et al.*, “LBNE Reconfiguration: Steering Committee Report,” 2012.
46 http://www.fnal.gov/directorate/lbne_reconfiguration/index.shtml. Cited
47 in Sections 1.2.2 (pg.7), 1.3 (pg.9), 4.2.1 (pg.86), and 9.3 (pg.210).
48. “Department of Energy Review Committee Report on the Technical, Cost, Schedule, and
49 Management Review of the Long Baseline Neutrino Experiment (LBNE),” October, 2012.
50 http://www.fnal.gov/directorate/OPMO/Projects/LBNE/DOERev/2012/10_30/1210_LBNE_rpt.pdf. Cited in Section 1.2.2 (pg.7).
51. “Independent Cost Review Closeout for the Long Baseline Neutrino Experiment (LBNE)
52 Project,” LBNE-doc-6522, November, 2012. Cited in Section 1.2.2 (pg.7).

- 14 28. “Critical Decision 1 Approve Alternative Selection and Cost Range of the Long Baseline
15 Neutrino Experiment (LBNE) Project,” LBNE-doc-6681, December, 2012. Cited in
16 Section 1.2.2 (pg.7).
- 17 29. **LBNE Project Management Team**, “LBNE Conceptual Design Report, Volume 1: The
18 LBNE Project,” LBNE-doc-5235, 2012. Cited in Sections 1.2.2 (pg.7), 4.2.2 (pg.88),
19 4.3 (pg.92), 4.3 (pg.95), 4.6 (pg.124), and A (pg.213).
- 20 30. **LBNE Project Management Team**, “LBNE Conceptual Design Report, Volume 2: The
21 Beamline at the Near Site,” LBNE-doc-4317, 2012. Cited in Sections 1.2.2 (pg.7),
22 3.4 (pg.63), and 4.3 (pg.93).
- 23 31. **LBNE Project Management Team**, “LBNE Conceptual Design Report, Volume 3:
24 Detectors at the Near Site,” LBNE-doc-4724, 2012. Cited in Sections 1.2.2 (pg.7)
25 and 3.5 (pg.73).
- 26 32. **LBNE Project Management Team**, “LBNE Conceptual Design Report, Volume 4: The
27 Liquid Argon Detector at the Far Site,” LBNE-doc-4892, 2012. Cited in
28 Sections 1.2.2 (pg.7) and 3.6.1 (pg.77).
- 29 33. **LBNE Project Management Team**, “LBNE Conceptual Design Report, Volume 5:
30 Conventional Facilities at the Near Site (MI-10 Shallow),” LBNE-doc-4623, 2012. Cited
31 in Section 1.2.2 (pg.7).
- 32 34. **LBNE Project Management Team**, “LBNE Conceptual Design Report, Volume 6:
33 Conventional Facilities at the Far Site,” LBNE-doc-5017, 2012. Cited in
34 Section 1.2.2 (pg.7).
- 35 35. R. J. Wilson, “Long-Baseline Neutrino Experiment, presentation, November 2013,” 2013.
36 <https://indico.fnal.gov/getFile.py/access?contribId=25&sessionId=7&resId=0&materialId=slides&confId=7485>. Cited in Section 1.2.3 (pg.8).
- 1 36. Marx-Reichanadter Committee, “Department of Energy Office of Science Review of
2 Options for Underground Science.” June, 2011. http://science.energy.gov/~media/np/pdf/review_of_underground_science_report_final.pdf. Cited in
3 Section 1.3 (pg.9).
- 5 37. Grannis, P. and Green, D. and Nishikawa, K. and Robertson, H. and Sadoulet, B. and Wark,
6 D., “The LBNE Science Capability Review,” LBNE-doc-5333, December, 2011. Cited in
7 Section 1.3 (pg.9).
- 8 38. M. Messier, **NOvA Collaboration**, “Extending the NOvA Physics Program,”
9 FERMILAB-CONF-13-308-E, arXiv:1308.0106 [hep-ex], 2013. Cited in
10 Sections 1.3.1 (pg.10) and 4.8 (pg.136).
- 11 39. P. Huber and J. Kopp, “Two experiments for the price of one? – The role of the second
12 oscillation maximum in long baseline neutrino experiments,” *JHEP* **1103** (2011) 013,
13 arXiv:1010.3706 [hep-ph]. Cited in Section 1.3.1 (pg.13).
- 14 40. E. Kearns, “Future Experiments for Proton Decay. Presentation at ISOUPS (International
15 Symposium: Opportunities in Underground Physics for Snowmass), Asilomar, May 2013,”
16 2013. Cited in Sections 1.3.2 (pg.13), 5.1 (pg.139), 5.1 (pg.140), and 5.2 (pg.141).

- 17 41. J. Strait, “Physics Research Goals After Reconfiguration,” LBNE-doc-3056, 2011. Cited
18 in Section 2.1 (pg.18).
- 19 42. R. Mohapatra, S. Antusch, K. Babu, G. Barenboim, M.-C. Chen, *et al.*, “Theory of
20 neutrinos: A White paper,” *Rept. Prog. Phys.* **70** (2007) 1757–1867,
21 arXiv:hep-ph/0510213 [hep-ph]. Cited in Sections 2.2 (pg.21) and 2.2 (pg.23).
- 22 43. G. Aad *et al.*, **ATLAS Collaboration**, “Observation of a new particle in the search for the
23 Standard Model Higgs boson with the ATLAS detector at the LHC,” *Phys. Lett.* **B716**
1 (2012) 1–29, arXiv:1207.7214 [hep-ex]. Cited in Section 2.2 (pg.21).
- 2 44. S. Chatrchyan *et al.*, **CMS Collaboration**, “Observation of a new boson at a mass of 125
3 GeV with the CMS experiment at the LHC,” *Phys. Lett.* **B716** (2012) 30–61,
4 arXiv:1207.7235 [hep-ex]. Cited in Section 2.2 (pg.21).
- 5 45. DNP/DPF/DAP/DPB Joint Study on the Future of Neutrino Physics, “The Neutrino
6 Matrix.”. November, 2004. <http://www.aps.org/policy/reports/multidivisional/neutrino/upload/main.pdf>.
7 Cited in Section 2.2 (pg.22).
- 9 46. F. An *et al.*, **Daya Bay Collaboration**, “Improved Measurement of Electron Antineutrino
10 Disappearance at Daya Bay,” *Chin. Phys.* **C37** (2013) 011001, arXiv:1210.6327
11 [hep-ex]. Cited in Section 2.2 (pg.22).
- 12 47. A. Aguilar-Arevalo *et al.*, **LSND Collaboration**, “Evidence for neutrino oscillations from
13 the observation of anti-neutrino(electron) appearance in a anti-neutrino(muon) beam,”
14 *Phys. Rev.* **D64** (2001) 112007, arXiv:hep-ex/0104049 [hep-ex]. Cited in
15 Section 2.2 (pg.23).
- 16 48. A. Aguilar-Arevalo *et al.*, **MiniBooNE Collaboration**, “A Search for electron neutrino
17 appearance at the $\Delta m^2 \sim 1\text{eV}^2$ scale,” *Phys. Rev. Lett.* **98** (2007) 231801,
18 arXiv:0704.1500 [hep-ex]. Cited in Section 2.2 (pg.23).
- 19 49. A. Aguilar-Arevalo *et al.*, **MiniBooNE Collaboration**, “Improved Search for $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$
20 Oscillations in the MiniBooNE Experiment,” *Phys. Rev. Lett.* **110** no. 16, (2013) 161801,
21 arXiv:1207.4809 [hep-ex]. Cited in Section 2.2 (pg.23).
- 22 50. G. Mention, M. Fechner, T. Lasserre, T. Mueller, D. Lhuillier, *et al.*, “The Reactor
23 Antineutrino Anomaly,” *Phys. Rev.* **D83** (2011) 073006, arXiv:1101.2755 [hep-ex].
24 Cited in Section 2.2 (pg.23).
- 25 51. S. F. King, A. Merle, S. Morisi, Y. Shimizu, and M. Tanimoto, “Neutrino Mass and
26 Mixing: from Theory to Experiment,” arXiv:1402.4271 [hep-ph], 2014. Cited in
27 Section 2.2 (pg.23).
- 28 52. P. Harrison, D. Perkins, and W. Scott, “Tri-bimaximal mixing and the neutrino oscillation
29 data,” *Phys. Lett.* **B530** (2002) 167, arXiv:hep-ph/0202074 [hep-ph]. Cited in
30 Section * (pg.23).
- 31 53. C. H. Albright and M.-C. Chen, “Model Predictions for Neutrino Oscillation Parameters,”
1 *Phys. Rev.* **D74** (2006) 113006, arXiv:hep-ph/0608137 [hep-ph]. Cited in
2 Section 2.2 (pg.23).

- 3 54. G. Fogli, E. Lisi, A. Marrone, D. Montanino, A. Palazzo, *et al.*, “Global analysis of
4 neutrino masses, mixings and phases: entering the era of leptonic CP violation searches,”
5 *Phys.Rev.* **D86** (2012) 013012, arXiv:1205.5254 [hep-ph]. Cited in Sections † (pg.24),
6 2.2.1 (pg.25), 4.3 (pg.92), 4.3 (pg.93), 4.3.2 (pg.110), and 4.4 (pg.117).
- 7 55. J. Beringer *et al.*, **Particle Data Group**, “Review of Particle Physics (RPP),” *Phys.Rev.*
8 **D86** (2012) 010001. Cited in Sections 2.2.1 (pg.25), 2.2.2 (pg.27), and 7.4.4 (pg.183).
- 9 56. C. Jarlskog, “A Basis Independent Formulation of the Connection Between Quark Mass
10 Matrices, CP Violation and Experiment,” *Z.Phys.* **C29** (1985) 491–497. Cited in
11 Section 2.2.1 (pg.24).
- 12 57. A. Meroni, S. Petcov, and M. Spinrath, “A SUSY SU(5)xT’ Unified Model of Flavour with
13 large θ_{13} ,” *Phys.Rev.* **D86** (2012) 113003, arXiv:1205.5241 [hep-ph]. Cited in
14 Section 2.2.1 (pg.25).
- 15 58. G.-J. Ding, S. F. King, and A. J. Stuart, “Generalised CP and A_4 Family Symmetry,” *JHEP*
16 **1312** (2013) 006, arXiv:1307.4212. Cited in Section 2.2.1 (pg.25).
- 17 59. C. Luhn, “Trimaximal TM₁ neutrino mixing in S_4 with spontaneous CP violation,”
18 *Nucl.Phys.* **B875** (2013) 80–100, arXiv:1306.2358 [hep-ph]. Cited in
19 Sections 2.2.1 (pg.25) and 2.2.6 (pg.35).
- 20 60. G.-J. Ding and Y.-L. Zhou, “Predicting Lepton Flavor Mixing from $\Delta(48)$ and Generalized
21 CP Symmetries,” arXiv:1312.5222 [hep-ph], 2013. Cited in Section 2.2.1 (pg.25).
- 22 61. S. Antusch, S. F. King, and M. Spinrath, “Spontaneous CP violation in $A_4 \times SU(5)$ with
23 Constrained Sequential Dominance 2,” *Phys.Rev.* **D87** no. 9, (2013) 096018,
24 arXiv:1301.6764 [hep-ph]. Cited in Section 2.2.1 (pg.25).
- 25 62. S. F. King, “A model of quark and lepton mixing,” *JHEP* **1401** (2014) 119,
26 arXiv:1311.3295 [hep-ph]. Cited in Section 2.2.1 (pg.25).
- 27 63. E. Kolb and M. Turner, *The Early Universe*. Westview Press, 1994. ISBN
28 978-0201626742. Cited in Section 2.2.1 (pg.25).
- 29 64. S. Weinberg, *Cosmology*. Oxford University Press, USA, first ed., April, 2008. ISBN
30 978-0198526827. Cited in Section 2.2.1 (pg.25).
- 31 65. G. Steigman, “Primordial Nucleosynthesis in the Precision Cosmology Era,”
32 *Ann.Rev.Nucl.Part.Sci.* **57** (2007) 463–491, arXiv:0712.1100 [astro-ph]. Cited in
33 Section 2.2.1 (pg.25).
- 34 66. M. Fukugita and T. Yanagida, “Baryogenesis Without Grand Unification,” *Phys.Lett.* **B174**
35 (1986) 45. Cited in Section 2.2.1 (pg.25).
- 36 67. T. Yanagida, “Horizontal Symmetry and Masses of Neutrinos,” *Prog.Theor.Phys.* **64** (1980)
37 1103. Cited in Sections 2.2.1 (pg.25), 7.7 (pg.187), and 9.2 (pg.209).
- 38 68. S. Pascoli, S. Petcov, and A. Riotto, “Leptogenesis and Low Energy CP Violation in
39 Neutrino Physics,” *Nucl.Phys.* **B774** (2007) 1–52, arXiv:hep-ph/0611338 [hep-ph].
1 Cited in Section 2.2.1 (pg.26).
- 2 69. F. Capozzi, G. Fogli, E. Lisi, A. Marrone, D. Montanino, *et al.*, “Status of three-neutrino
3 oscillation parameters, circa 2013,” arXiv:1312.2878 [hep-ph], 2013. Cited in
4 Sections 2.2.1 (pg.26), 4.3.1 (pg.99), 4.3.3 (pg.112), 4.4 (pg.115), and 9.2 (pg.208).

- 5 70. P. Adamson *et al.*, **MINOS Collaboration**, “Search for the disappearance of muon
6 antineutrinos in the NuMI neutrino beam,” *Phys.Rev.* **D84** (2011) 071103,
7 arXiv:1108.1509 [hep-ex]. Cited in Section 2.2.2 (pg.26).
- 8 71. S. Mikheev and A. Y. Smirnov, “Resonance Amplification of Oscillations in Matter and
9 Spectroscopy of Solar Neutrinos,” *Sov.J.Nucl.Phys.* **42** (1985) 913–917. Cited in
10 Section 2.2.2 (pg.27).
- 11 72. L. Wolfenstein, “Neutrino Oscillations in Matter,” *Phys.Rev.* **D17** (1978) 2369–2374. Cited
12 in Section 2.2.2 (pg.27).
- 13 73. G. Bellini *et al.*, **Borexino Collaboration**, “Measurement of the solar 8B neutrino rate
14 with a liquid scintillator target and 3 MeV energy threshold in the Borexino detector,”
15 *Phys.Rev.* **D82** (2010) 033006, arXiv:0808.2868 [astro-ph]. Cited in
16 Section 2.2.2 (pg.27).
- 17 74. G. Bellini, J. Benziger, D. Bick, S. Bonetti, G. Bonfini, *et al.*, “Precision measurement of
18 the 7Be solar neutrino interaction rate in Borexino,” *Phys.Rev.Lett.* **107** (2011) 141302,
19 arXiv:1104.1816 [hep-ex]. Cited in Section 2.2.2 (pg.27).
- 20 75. B. Aharmim *et al.*, **SNO Collaboration**, “Combined Analysis of all Three Phases of Solar
21 Neutrino Data from the Sudbury Neutrino Observatory,” *Phys.Rev.* **C88** (2013) 025501,
22 arXiv:1109.0763 [nucl-ex]. Cited in Section 2.2.2 (pg.27).
- 23 76. A. Renshaw *et al.*, **Super-Kamiokande Collaboration**, “First Indication of Terrestrial
24 Matter Effects on Solar Neutrino Oscillation,” arXiv:1312.5176 [hep-ex], 2013. Cited
25 in Sections 2.2.2 (pg.27) and 8.1 (pg.199).
- 26 77. M. Freund, “Analytic approximations for three neutrino oscillation parameters and
27 probabilities in matter,” *Phys.Rev.* **D64** (2001) 053003, arXiv:hep-ph/0103300
28 [hep-ph]. Cited in Section 2.2.2 (pg.27).
- 29 78. W. Marciano and Z. Parsa, “Intense neutrino beams and leptonic CP violation,”
30 *Nucl.Phys.Proc.Suppl.* **221** (2011) 166–172, arXiv:hep-ph/0610258 [hep-ph]. Cited
31 in Section 2.2.2 (pg.30).
- 32 79. B. Viren, “libnuosc++ - A library for calculating 3 neutrino oscillation probabilities..”
33 <https://github.com/brettviren/nuosc>. Cited in Section 2.2.3 (pg.30).
- 34 80. A. M. Dziewonski and D. L. Anderson, “Preliminary reference Earth model,” *Phys. Earth
35 Plan. Int.* **25** (1981) 297. Cited in Section 2.2.3 (pg.30).
- 36 81. J. Appel *et al.*, “Physics Working Group Report to the LBNE Reconfiguration Steering
1 Committee,” 2012. [http://www.fnal.gov/directorate/lbne_reconfiguration/
2 files/LBNE-Reconfiguration-PhysicsWG-Report-August2012.pdf](http://www.fnal.gov/directorate/lbne_reconfiguration/files/LBNE-Reconfiguration-PhysicsWG-Report-August2012.pdf). Cited in
3 Section 2.2.5 (pg.35).
- 4 82. R. Brun, F. Bruyant, M. Maire, A. McPherson, and P. Zanarini, “GEANT3,”
5 CERN-DD-EE-84-1, 1987. Cited in Section 2.2.5 (pg.33).
- 6 83. M. Bass *et al.*, **LBNE Collaboration**, “Baseline optimization for the measurement of CP
7 violation and mass hierarchy in a long-baseline neutrino oscillation experiment,”
8 FERMILAB-PUB-13-506-E, arXiv:1311.0212 [hep-ex], 2013. Cited in
9 Sections 2.2.5 (pg.35) and 3.1 (pg.47).

84. M. Raidal, “Relation between the neutrino and quark mixing angles and grand unification,” *Phys.Rev.Lett.* **93** (2004) 161801, arXiv:hep-ph/0404046 [hep-ph]. Cited in Section 2.2.6 (pg.35).
85. H. Minakata and A. Y. Smirnov, “Neutrino mixing and quark-lepton complementarity,” *Phys.Rev.* **D70** (2004) 073009, arXiv:hep-ph/0405088 [hep-ph]. Cited in Section 2.2.6 (pg.35).
86. A. Y. Smirnov, “Neutrino mass, mixing and discrete symmetries,” *J.Phys.Conf.Ser.* **447** (2013) 012004, arXiv:1305.4827 [hep-ph]. Cited in Section 2.2.6 (pg.35).
87. J. Harada, “Non-maximal θ_{23} , large θ_{13} and tri-bimaximal θ_{12} via quark-lepton complementarity at next-to-leading order,” *Europhys.Lett.* **103** (2013) 21001, arXiv:1304.4526 [hep-ph]. Cited in Section 2.2.6 (pg.35).
88. B. Hu, “Trimaximal-Cabibbo neutrino mixing: A parametrization in terms of deviations from tribimaximal mixing,” *Phys.Rev.* **D87** no. 5, (2013) 053011, arXiv:1212.4079 [hep-ph]. Cited in Section 2.2.6 (pg.35).
89. P. Ramond, “Fundamental Physics Underground. Presentation at ISOUPS (International Symposium: Opportunities in Underground Physics for Snowmass), Asilomar, May 2013,” 2013. Cited in Section 2.2.6 (pg.35).
90. S. Antusch, C. Biggio, E. Fernandez-Martinez, M. Gavela, and J. Lopez-Pavon, “Unitarity of the Leptonic Mixing Matrix,” *JHEP* **0610** (2006) 084, arXiv:hep-ph/0607020 [hep-ph]. Cited in Section 2.2.6 (pg.35).
91. X. Qian, C. Zhang, M. Diwan, and P. Vogel, “Unitarity Tests of the Neutrino Mixing Matrix,” arXiv:1308.5700 [hep-ex], 2013. Cited in Sections 2.2.6 (pg.35) and 2.2.6 (pg.36).
92. J. C. Pati and A. Salam, “Is Baryon Number Conserved?,” *Phys.Rev.Lett.* **31** (1973) 661–664. Cited in Section 2.3.1 (pg.38).
93. H. Georgi and S. Glashow, “Unity of All Elementary Particle Forces,” *Phys.Rev.Lett.* **32** (1974) 438–441. Cited in Section 2.3.1 (pg.38).
94. S. Dimopoulos, S. Raby, and F. Wilczek, “Proton Decay in Supersymmetric Models,” *Phys.Lett.* **B112** (1982) 133. Cited in Section 2.3.1 (pg.38).
95. P. Langacker, “Grand Unified Theories and Proton Decay,” *Phys.Rept.* **72** (1981) 185. Cited in Section 2.3.1 (pg.38).
96. W. de Boer, “Grand unified theories and supersymmetry in particle physics and cosmology,” *Prog.Part.Nucl.Phys.* **33** (1994) 201–302, arXiv:hep-ph/9402266 [hep-ph]. Cited in Section 2.3.1 (pg.38).
97. P. Nath and P. Fileviez Perez, “Proton stability in grand unified theories, in strings and in branes,” *Phys.Rept.* **441** (2007) 191–317, arXiv:hep-ph/0601023 [hep-ph]. Cited in Section 2.3.1 (pg.38).
98. S. Raby, T. Walker, K. Babu, H. Baer, A. Balantekin, *et al.*, “DUSEL Theory White Paper,” SLAC-PUB-14734, FERMILAB-PUB-08-680-T, arXiv:0810.4551 [hep-ph], 2008. Cited in Section 2.3.1 (pg.38).

- 6 99. G. Senjanovic, “Proton decay and grand unification,” *AIP Conf.Proc.* **1200** (2010)
 7 131–141, arXiv:0912.5375 [hep-ph]. Cited in Section 2.3.1 (pg.38).
- 8 100. T. Li, D. V. Nanopoulos, and J. W. Walker, “Elements of F-ast Proton Decay,” *Nucl.Phys.*
 9 **B846** (2011) 43–99, arXiv:1003.2570 [hep-ph]. Cited in Section 2.3.1 (pg.38).
- 10 101. E. Noether, “Invariant Variation Problems,” *Gott.Nachr.* **1918** (1918) 235–257,
 11 arXiv:physics/0503066 [physics]. Cited in Section 2.3.1 (pg.39).
- 12 102. H. Nishino *et al.*, **Super-Kamiokande Collaboration**, “Search for Nucleon Decay into
 13 Charged Anti-lepton plus Meson in Super-Kamiokande I and II,” *Phys.Rev.* **D85** (2012)
 14 112001, arXiv:1203.4030 [hep-ex]. Cited in Section 2.3.2 (pg.40).
- 15 103. R. Bionta, G. Blewitt, C. Bratton, D. Casper, A. Ciocio, *et al.*, “Observation of a Neutrino
 16 Burst in Coincidence with Supernova SN 1987a in the Large Magellanic Cloud,”
 17 *Phys.Rev.Lett.* **58** (1987) 1494. Cited in Sections 2.4 (pg.42) and 6.1 (pg.151).
- 18 104. K. Hirata *et al.*, **KAMIOKANDE-II Collaboration**, “Observation of a Neutrino Burst
 19 from the Supernova SN 1987a,” *Phys.Rev.Lett.* **58** (1987) 1490–1493. Cited in
 20 Sections 2.4 (pg.42) and 6.1 (pg.151).
- 21 105. E. Alekseev, L. Alekseeva, V. Volchenko, and I. Krivosheina, “Possible Detection of a
 22 Neutrino Signal on 23 February 1987 at the Baksan Underground Scintillation Telescope
 1 of the Institute of Nuclear Research,” *JETP Lett.* **45** (1987) 589–592. Cited in
 2 Section 2.4 (pg.42).
- 3 106. K. Scholberg, “Supernova neutrino detection,” *Nucl.Phys.Proc.Suppl.* **221** (2011) 248–253,
 1 arXiv:astro-ph/0701081 [astro-ph]. Cited in Sections 2.4 (pg.42) and 2.4 (pg.44).
- 2 107. A. Dighe, “Physics potential of future supernova neutrino observations,” *J.Phys.Conf.Ser.*
 3 **136** (2008) 022041, arXiv:0809.2977 [hep-ph]. Cited in Section 2.4 (pg.42).
- 4 108. G. A. Tammann, W. Loeffler, and A. Schroder, “The Galactic supernova rate,” *Astrophys. J.*
 5 *Suppl.* **92** (1994) 487–493. Cited in Section 2.4 (pg.42).
- 6 109. E. Cappellaro, R. Evans, and M. Turatto, “A new determination of supernova rates and a
 7 comparison with indicators for galactic star formation,” *Astron.Astrophys.* **351** (1999) 459,
 8 arXiv:astro-ph/9904225 [astro-ph]. Cited in Section 2.4 (pg.42).
- 9 110. G. Pagliaroli, F. Vissani, E. Coccia, and W. Fulgione, “Neutrinos from Supernovae as a
 10 Trigger for Gravitational Wave Search,” *Phys. Rev. Lett.* **103** (2009) 031102,
 11 arXiv:0903.1191 [hep-ph]. Cited in Section 2.4 (pg.43).
- 12 111. C. Ott, E. O’Connor, S. Gossan, E. AbdiKamalov, U. Gamma, *et al.*, “Core-Collapse
 13 Supernovae, Neutrinos, and Gravitational Waves,” *Nucl.Phys.Proc.Suppl.* **235-236** (2013)
 14 381–387, arXiv:1212.4250 [astro-ph.HE]. Cited in Section 2.4 (pg.43).
- 15 112. A. Mirizzi, G. Raffelt, and P. Serpico, “Earth matter effects in supernova neutrinos:
 16 Optimal detector locations,” *JCAP* **0605** (2006) 012, arXiv:astro-ph/0604300
 17 [astro-ph]. Cited in Sections 2.4 (pg.43) and 2.4 (pg.44).
- 18 113. S. Choubey, B. Dasgupta, A. Dighe, and A. Mirizzi, “Signatures of collective and matter
 19 effects on supernova neutrinos at large detectors,” arXiv:1008.0308 [hep-ph], 2010.
 20 Cited in Section 2.4 (pg.43).

- 21 114. G. G. Raffelt, “Astrophysical axion bounds: An Update,” arXiv:astro-ph/9707268
22 [astro-ph], 1997. Cited in Section 2.4 (pg.43).
- 23 115. S. Hannestad and G. Raffelt, “New supernova limit on large extra dimensions,”
24 *Phys.Rev.Lett.* **87** (2001) 051301, arXiv:hep-ph/0103201 [hep-ph]. Cited in
25 Section 2.4 (pg.43).
- 26 116. P. Antonioli *et al.*, “Snews: The supernova early warning system,” *New J. Phys.* **6** (2004)
27 114, astro-ph/0406214. Cited in Sections 2.4 (pg.44) and 6.1 (pg.153).
- 28 117. K. Scholberg, “The SuperNova Early Warning System,” *Astron. Nachr.* **329** (2008)
29 337–339, arXiv:0803.0531 [astro-ph]. Cited in Sections 2.4 (pg.44)
30 and 6.1 (pg.153).
- 31 118. K. Scholberg, “Future supernova neutrino detectors,” *J.Phys.Conf.Ser.* **203** (2010) 012079.
32 Cited in Section 2.4 (pg.44).
- 33 119. “Sanford Underground Research Facility.” <http://www.sanfordlab.org>. Cited in
34 Section 3.3 (pg.54).
- 35 120. B. Cleveland, T. Daily, R. Davis Jr., J. R. Distel, K. Lande, *et al.*, “Measurement of the
1 solar electron neutrino flux with the Homestake chlorine detector,” *Astrophys.J.* **496** (1998)
2 505–526. Cited in Sections 3.3 (pg.54) and 8.1 (pg.195).
- 3 121. F. Gray, C. Ruybal, J. Totushek, D.-M. Mei, K. Thomas, *et al.*, “Cosmic Ray Muon Flux at
4 the Sanford Underground Laboratory at Homestake,” *Nucl.Instrum.Meth.* **A638** (2011)
5 63–66, arXiv:1007.1921 [nucl-ex]. Cited in Section 3.3 (pg.58).
- 6 122. W. Roggenthen and A. Smith, “U, Th, K contents of materials associated with the
7 Homestake DUSEL site, Lead, South Dakota,” *Private Communication*. Cited in
8 Section 3.3 (pg.59).
- 9 123. D. Akerib *et al.*, **LUX Collaboration**, “First results from the LUX dark matter experiment
10 at the Sanford Underground Research Facility,” arXiv:1310.8214 [astro-ph.CO],
11 2013. Cited in Section 3.3 (pg.59).
- 12 124. M. Bishai and Y. Lu, “Conceptual Designs for a Wide-Band Low-Energy Neutrino Beam
13 Target,” LBNE-doc-3151, November, 2010.
- 14 125. B. Lundberg, “A beginner guide to horn design and history of LBNE horn design,”
15 LBNE-doc-8398, November, 2014.
- 16 126. D. Ayres *et al.*, **NOvA Collaboration**, “The NOvA Technical Design Report,”
17 FERMILAB-DESIGN-2007-01, 2007.
18 <http://lss.fnal.gov/archive/design/fermilab-design-2007-01.pdf>. Cited in
19 Sections 3.4 (pg.63), 4.2.1 (pg.88), 7.4.4 (pg.183), and 7.6 (pg.185).
- 20 127. E. Worcester, “Potential Sensitivity Improvements with 10 kT LBNE,” LBNE-doc-6599,
21 2012. Cited in Section 3.4 (pg.69).
- 22 128. S. Mishra, R. Petti, and C. Rosenfeld, “A High Resolution Neutrino Experiment in a
23 Magnetic Field for Project-X at Fermilab,” *PoS NUFACt08* (2008) 069,
24 arXiv:0812.4527 [hep-ex]. Cited in Section 3.5 (pg.71).

- 25 129. B. Choudhary *et al.*, **Indian Institutions and Fermilab Collaboration** , “LBNE-India
26 Detailed Project Report (DPR) submitted to DAE, India,” LBNE-doc-6704, 2012. Cited in
27 Sections 3.5 (pg.73), 3.5 (pg.74), and 7 (pg.163).
- 28 130. P. Huber, M. Lindner, and W. Winter, “Simulation of long-baseline neutrino oscillation
29 experiments with GLoBES (General Long Baseline Experiment Simulator),”
30 *Comput.Phys.Commun.* **167** (2005) 195, arXiv:hep-ph/0407333 [hep-ph]. Cited in
31 Sections 4.2 (pg.85), 4.2.1 (pg.86), 4.2.2 (pg.88), and A.3 (pg.225).
- 32 131. P. Huber, J. Kopp, M. Lindner, M. Rolinec, and W. Winter, “New features in the simulation
33 of neutrino oscillation experiments with GLoBES 3.0: General Long Baseline Experiment
34 Simulator,” *Comput.Phys.Commun.* **177** (2007) 432–438, arXiv:hep-ph/0701187
35 [hep-ph]. Cited in Sections 4.2 (pg.85) and 4.2.2 (pg.88).
- 36 132. S. Agostinelli *et al.*, **GEANT4** , “GEANT4: A simulation toolkit,” *Nucl. Instrum. Meth.*
37 **A506** (2003) 250–303. Cited in Sections 4.2.1 (pg.85), 6.2 (pg.154), and A.1.1 (pg.213).
- 1 133. C. Andreopoulos, **GENIE Collaboration** , “The GENIE neutrino Monte Carlo generator,”
2 *Acta Phys.Polon.* **B40** (2009) 2461–2475. Cited in Sections 4.2.1 (pg.88), 4.6 (pg.122),
3 and A.1.1 (pg.216).
- 4 134. K. Abe *et al.*, **T2K Collaboration** , “The T2K Experiment,” *Nucl.Instrum.Meth.* **A659**
5 (2011) 106–135, arXiv:1106.1238 [physics.ins-det]. Cited in
6 Sections 4.2.1 (pg.88), 7.4.4 (pg.183), and 7.6 (pg.185).
- 7 135. **NuMI-MINOS** . <http://www-numi.fnal.gov/>. Cited in Section 4.2.1 (pg.88).
- 8 136. A. Rubbia, “LAGUNA-LBNO: Design of an underground neutrino observatory coupled to
9 long baseline neutrino beams from CERN,” *J.Phys.Conf.Ser.* **408** (2013) 012006. Cited in
10 Section 4.2.1 (pg.88).
- 11 137. J.-P. Delahaye, C. Ankenbrandt, A. Bogacz, S. Brice, A. Bross, *et al.*, “Enabling Intensity
12 and Energy Frontier Science with a Muon Accelerator Facility in the U.S.: A White Paper
1 Submitted to the 2013 U.S. Community Summer Study of the Division of Particles and
2 Fields of the American Physical Society,” FERMILAB-CONF-13-307-APC,
3 arXiv:1308.0494 [physics.acc-ph], 2013. Cited in Section 4.2.1 (pg.88).
- 4 138. A. Longhin, “Optimization of neutrino beams for underground sites in Europe,”
5 arXiv:1206.4294 [physics.ins-det], 2012. Cited in Section 4.2.1 (pg.88).
- 6 139. S. Amoruso *et al.*, **ICARUS Collaboration** , “Measurement of the mu decay spectrum
7 with the ICARUS liquid argon TPC,” *Eur.Phys.J.* **C33** (2004) 233–241,
8 arXiv:hep-ex/0311040 [hep-ex]. Cited in Sections 4.2.2 (pg.88), 4.6 (pg.124),
9 and 6.2 (pg.154).
- 10 140. T2K Collaboration, “A Proposal for a Detector 2km Away from the T2K Neutrino
11 Source.”. 2005. <http://www.phy.duke.edu/~cwalter/nusag-members/2km-proposal-05-05-30.pdf>.
12 Cited in Section 4.2.2 (pg.89).
- 13 141. A. Ankowski *et al.*, **ICARUS Collaboration** , “Measurement of through-going particle
14 momentum by means of multiple scattering with the ICARUS T600 TPC,” *Eur.Phys.J.* **C48**
15 (2006) 667–676, arXiv:hep-ex/0606006 [hep-ex]. Cited in Section 4.2.2 (pg.89).

- 2 142. F. An *et al.*, **Daya Bay Collaboration**, “Spectral measurement of electron antineutrino
3 oscillation amplitude and frequency at Daya Bay,” arXiv:1310.6732 [hep-ex], 2013.
4 Cited in Sections 4.3 (pg.93) and 4.5 (pg.119).
- 5 143. P. Adamson *et al.*, **MINOS Collaboration**, “Electron neutrino and antineutrino
6 appearance in the full MINOS data sample,” *Phys.Rev.Lett.* **110** no. 17, (2013) 171801,
7 arXiv:1301.4581 [hep-ex]. Cited in Sections 4.3 (pg.93), 4.3.2 (pg.103),
8 and 4.3.2 (pg.108).
- 9 144. M. J. Murtagh, **E734 Collaboration**, “A Search for muon-neutrino to electron-neutrino
10 oscillations using the E734 detector,” BNL-39667, 1987.
- 11 145. R. Seto, “BNL E776: A Search for neutrino oscillations,” *AIP Conf.Proc.* **176** (1988)
12 957–963.
- 13 146. L. Borodovsky, C. Chi, Y. Ho, N. Kondakis, W.-Y. Lee, *et al.*, “Search for muon-neutrino
14 oscillations muon-neutrino to electron-neutrino (anti-muon-neutrino to
15 anti-electron-neutrino in a wide band neutrino beam,” *Phys.Rev.Lett.* **68** (1992) 274–277.
- 16 147. P. Astier *et al.*, **NOMAD Collaboration**, “Search for nu(mu) → nu(e) oscillations in the
17 NOMAD experiment,” *Phys.Lett.* **B570** (2003) 19–31, arXiv:hep-ex/0306037
18 [hep-ex].
- 19 148. A. Aguilar-Arevalo *et al.*, **MiniBooNE Collaboration**, “Unexplained Excess of
20 Electron-Like Events From a 1-GeV Neutrino Beam,” *Phys.Rev.Lett.* **102** (2009) 101802,
21 arXiv:0812.2243 [hep-ex]. Cited in Section 7.7 (pg.190).
- 22 149. K. Abe *et al.*, **T2K Collaboration**, “Observation of Electron Neutrino Appearance in a
23 Muon Neutrino Beam,” arXiv:1311.4750 [hep-ex], 2013. Cited in
24 Section 4.3.2 (pg.103).
- 25 150. X. Qian, A. Tan, W. Wang, J. Ling, R. McKeown, *et al.*, “Statistical Evaluation of
26 Experimental Determinations of Neutrino Mass Hierarchy,” *Phys.Rev.* **D86** (2012) 113011,
27 arXiv:1210.3651 [hep-ph]. Cited in Sections 4.3.1 (pg.96), 4.3.1 (pg.97),
28 4.3.1 (pg.99), and 4.3.1 (pg.100).
- 29 151. M. Blennow, P. Coloma, P. Huber, and T. Schwetz, “Quantifying the sensitivity of
30 oscillation experiments to the neutrino mass ordering,” arXiv:1311.1822 [hep-ph],
31 2013. Cited in Sections 4.3.1 (pg.97), 4.3.1 (pg.98), 4.3.1 (pg.99), 4.3.1 (pg.100),
32 and 4.8 (pg.137).
- 33 152. R. Cousins, “Private communication,” 2013. Cited in Section 4.3.1 (pg.99).
- 34 153. R. Cousins, J. Mumford, J. Tucker, and V. Valuev, “Spin discrimination of new heavy
35 resonances at the LHC,” *JHEP* **0511** (2005) 046. Cited in Section 4.3.1 (pg.99).
- 36 154. P. Adamson *et al.*, **MINOS Collaboration**, “Improved search for muon-neutrino to
1 electron-neutrino oscillations in MINOS,” *Phys.Rev.Lett.* **107** (2011) 181802,
2 arXiv:1108.0015 [hep-ex]. Cited in Section 4.3.2 (pg.103).
- 3 155. P. Adamson *et al.*, **MINOS Collaboration**, “Neutrino and Antineutrino Inclusive
4 Charged-current Cross Section Measurements with the MINOS Near Detector,” *Phys.Rev.*
5 **D81** (2010) 072002, arXiv:0910.2201 [hep-ex]. Cited in Sections 4.3.2 (pg.103)
6 and 7.1.8 (pg.169).

- 7 156. Q. Wu *et al.*, **NOMAD Collaboration**, “A Precise measurement of the muon
8 neutrino-nucleon inclusive charged current cross-section off an isoscalar target in the
9 energy range $2.5 < E(\nu) < 40$ -GeV by NOMAD,” *Phys.Lett.* **B660** (2008) 19–25,
10 arXiv:0711.1183 [hep-ex]. Cited in Sections 4.3.2 (pg.103), 7.1.8 (pg.169),
11 and 7.4.4 (pg.183).
- 12 157. V. Lyubushkin *et al.*, **NOMAD Collaboration**, “A Study of quasi-elastic muon neutrino
13 and antineutrino scattering in the NOMAD experiment,” *Eur.Phys.J.* **C63** (2009) 355–381,
14 arXiv:0812.4543 [hep-ex]. Cited in Sections 4.3.2 (pg.103) and 7.1.8 (pg.169).
- 15 158. A. Bodek, U. Sarica, K. Kuzmin, and V. Naumov, “Extraction of Neutrino Flux with the
16 Low ν Method at MiniBooNE Energies,” *AIP Conf.Proc.* **1560** (2013) 193–197,
17 arXiv:1207.1247 [hep-ex]. Cited in Section 4.3.2 (pg.103).
- 18 159. P. Adamson *et al.*, **MINOS Collaboration**, “A Study of Muon Neutrino Disappearance
19 Using the Fermilab Main Injector Neutrino Beam,” *Phys.Rev.* **D77** (2008) 072002,
20 arXiv:0711.0769 [hep-ex]. Cited in Section 4.3.2 (pg.103).
- 21 160. M. Bishai, “Determining the Neutrino Flux from Accelerator Neutrino Beams,”
22 *Nucl.Phys.Proc.Suppl.* **229-232** (2012) 210–214. Cited in Section 4.3.2 (pg.103).
- 23 161. B. Osmanov, **MINERvA Collaboration**, “MINERvA Detector: Description and
24 Performance,” arXiv:1109.2855 [physics.ins-det], 2011. Cited in
25 Sections 4.3.2 (pg.104), 7.4.4 (pg.182), 7.4.4 (pg.183), and 7.6 (pg.185).
- 26 162. A. Korzenev, **NA61/SHINE**, “Hadron production measurement from NA61/SHINE,”
27 arXiv:1311.5719 [nucl-ex], 2013. Cited in Sections 4.3.2 (pg.104)
28 and 7.1.2 (pg.166).
- 29 163. P. Adamson *et al.*, **MINOS Collaboration**, “Measurement of the neutrino mass splitting
30 and flavor mixing by MINOS,” *Phys.Rev.Lett.* **106** (2011) 181801, arXiv:1103.0340
31 [hep-ex]. Cited in Sections 4.3.2 (pg.105) and 4.5 (pg.120).
- 32 164. T. Yang, **ArgoNeuT Collaboration**, “New Results from ArgoNeuT,”
33 FERMILAB-CONF-13-510-E, arXiv:1311.2096 [hep-ex], 2013. Cited in
34 Section 4.3.2 (pg.107).
- 35 165. M. Day and K. S. McFarland, “Differences in Quasi-Elastic Cross-Sections of Muon and
1 Electron Neutrinos,” *Phys.Rev.* **D86** (2012) 053003, arXiv:1206.6745 [hep-ph]. Cited
2 in Section 4.3.2 (pg.108).
- 3 166. K. Abe *et al.*, **Super-Kamiokande Collaboration**, “Search for Differences in Oscillation
4 Parameters for Atmospheric Neutrinos and Antineutrinos at Super-Kamiokande,”
5 *Phys.Rev.Lett.* **107** (2011) 241801, arXiv:1109.1621 [hep-ex]. Cited in
6 Section 4.4 (pg.115).
- 7 167. P. Adamson *et al.*, **MINOS Collaboration**, “Measurement of Neutrino and Antineutrino
8 Oscillations Using Beam and Atmospheric Data in MINOS,” *Phys.Rev.Lett.* **110** (2013)
9 251801, arXiv:1304.6335 [hep-ex]. Cited in Section 4.6 (pg.122).
- 10 168. V. Agrawal, T. Gaisser, P. Lipari, and T. Stanev, “Atmospheric neutrino flux above 1-GeV,”
11 *Phys.Rev.* **D53** (1996) 1314–1323, arXiv:hep-ph/9509423 [hep-ph]. Cited in
12 Section 4.6 (pg.122).

- 1 169. A. Ankowski *et al.*, “Energy reconstruction of electromagnetic showers from pi0 decays
2 with the icarus t600 liquid argon tpc,” *Acta Physica Polonica B* **41** no. 1, (2010) 103,
3 arXiv:0812.2373 [hep-ex]. Cited in Section 4.6 (pg.124).
- 4 170. F. Arneodo *et al.*, **The ICARUS-Milano Collaboration** , “Performance of a liquid argon
5 time projection chamber exposed to the cern west area neutrino facility neutrino beam,”
6 *Phys. Rev. D* **74** (Dec, 2006) 112001.
7 <http://link.aps.org/doi/10.1103/PhysRevD.74.112001>. Cited in
8 Section 4.6 (pg.124).
- 9 171. C. Rubbia *et al.*, “Underground operation of the ICARUS T600 LAr-TPC: first results,”
10 *JINST* **6** (2011) P07011, arXiv:1106.0975 [hep-ex]. Cited in Section 4.6 (pg.124).
- 11 172. S. Davidson, C. Pena-Garay, N. Rius, and A. Santamaria, “Present and future bounds on
12 nonstandard neutrino interactions,” *JHEP* **0303** (2003) 011, arXiv:hep-ph/0302093
13 [hep-ph]. Cited in Section 4.7.1 (pg.132).
- 1 173. M. Gonzalez-Garcia and M. Maltoni, “Phenomenology with Massive Neutrinos,”
2 *Phys.Rept.* **460** (2008) 1–129, arXiv:0704.1800 [hep-ph]. Cited in
3 Section 4.7.1 (pg.132).
- 4 174. C. Biggio, M. Blennow, and E. Fernandez-Martinez, “General bounds on non-standard
5 neutrino interactions,” *JHEP* **0908** (2009) 090, arXiv:0907.0097 [hep-ph]. Cited in
6 Section 4.7.1 (pg.132).
- 7 175. H. Davoudiasl, H.-S. Lee, and W. J. Marciano, “Long-Range Lepton Flavor Interactions
8 and Neutrino Oscillations,” *Phys.Rev.* **D84** (2011) 013009, arXiv:1102.5352 [hep-ph].
9 Cited in Section 4.7.2 (pg.132).
- 10 176. P. Adamson *et al.*, **MINOS Collaboration** , “Search for sterile neutrino mixing in the
11 MINOS long baseline experiment,” *Phys.Rev.* **D81** (2010) 052004, arXiv:1001.0336
12 [hep-ex]. Cited in Section 4.7.3 (pg.134).
- 13 177. P. Machado, H. Nunokawa, F. P. d. Santos, and R. Z. Funchal, “Large Extra Dimensions
14 and Neutrino Oscillations,” arXiv:1110.1465 [hep-ph], 2011. Cited in
15 Section 4.7.4 (pg.135).
- 16 178. P. Coloma, P. Huber, J. Kopp, and W. Winter, “Systematic uncertainties in long-baseline
17 neutrino oscillations for large θ_{13} ,” *Phys.Rev.* **D87** no. 3, (2013) 033004,
18 arXiv:1209.5973 [hep-ph]. Cited in Section 4.8 (pg.135).
- 19 179. K. Abe, T. Abe, H. Aihara, Y. Fukuda, Y. Hayato, *et al.*, “Letter of Intent: The
20 Hyper-Kamiokande Experiment — Detector Design and Physics Potential —,”
21 arXiv:1109.3262 [hep-ex], 2011. Cited in Section 4.8 (pg.135).
- 22 180. A. Stahl, C. Wiebusch, A. Guler, M. Kamiscioglu, R. Sever, *et al.*, “Expression of Interest
23 for a very long baseline neutrino oscillation experiment (LBNO),” CERN-SPSC-2012-021,
24 SPSC-EOI-007, 2012. Cited in Section 4.8 (pg.135).
- 25 181. M. Apollonio, A. Bross, J. Kopp, and K. Long, **IDS-NF Collaboration** , “The
26 International Design Study for the Neutrino Factory,” *Nucl.Phys.Proc.Suppl.* **229-232**
27 (2012) 515. Cited in Section 4.8 (pg.135).

- 28 182. E. Christensen, P. Coloma, and P. Huber, “Physics Performance of a Low-Luminosity Low
 29 Energy Neutrino Factory,” arXiv:1301.7727 [hep-ph], 2013. Cited in
 30 Section 4.8 (pg.136).
- 31 183. E. Kearns *et al.*, **Hyper-Kamiokande Working Group**, “Hyper-Kamiokande Physics
 32 Opportunities,” arXiv:1309.0184 [hep-ex], 2013. Cited in Section 4.8 (pg.136).
- 33 184. S. Agarwalla *et al.*, **LAGUNA-LBNO Collaboration**, “The mass-hierarchy and
 34 CP-violation discovery reach of the LBNO long-baseline neutrino experiment,”
 1 arXiv:1312.6520 [hep-ph], 2013. Cited in Section 4.8 (pg.136).
- 2 185. M. Bishai, M. Diwan, S. Kettell, J. Stewart, B. Viren, *et al.*, “Precision Neutrino
 3 Oscillation Measurements using Simultaneous High-Power, Low-Energy Project-X
 4 Beams,” BNL-101234-2013-CP, FERMILAB-FN-0962, arXiv:1307.0807 [hep-ex],
 5 2013. Cited in Section 4.8 (pg.137).
- 6 186. J. L. Raaf, **Super-Kamiokande Collaboration**, “Recent Nucleon Decay Results from
 7 Super-Kamiokande,” *Nucl.Phys.Proc.Suppl.* **229-232** (2012) 559. Cited in
 8 Section 5.1 (pg.139).
- 9 187. A. Bueno, Z. Dai, Y. Ge, M. Laffranchi, A. Melgarejo, *et al.*, “Nucleon decay searches with
 10 large liquid argon TPC detectors at shallow depths: Atmospheric neutrinos and cosmogenic
 11 backgrounds,” *JHEP* **0704** (2007) 041, arXiv:hep-ph/0701101 [hep-ph]. Cited in
 12 Sections 5.1 (pg.140), 5.2 (pg.140), 5.3.1 (pg.144), 5.3.1 (pg.145), and 5.3.2 (pg.145).
- 13 188. D. Stefan and A. M. Ankowski, “Nuclear effects in proton decay,” *Acta Phys.Polon.* **B40**
 14 (2009) 671–674, arXiv:0811.1892 [nucl-th]. Cited in Section 5.2 (pg.141).
- 1 189. S. Amerio *et al.*, **ICARUS Collaboration**, “Design, construction and tests of the ICARUS
 2 T600 detector,” *Nucl.Instrum.Meth.* **A527** (2004) 329–410. Cited in Section 5.2 (pg.141).
- 3 190. M. Antonello, B. Baibussinov, P. Benetti, E. Calligarich, N. Canci, *et al.*, “Precise 3D track
 4 reconstruction algorithm for the ICARUS T600 liquid argon time projection chamber
 5 detector,” *Adv.High Energy Phys.* **2013** (2013) 260820, arXiv:1210.5089
 6 [physics.ins-det]. Cited in Sections 5.2 (pg.142) and 5.3.2 (pg.148).
- 7 191. A. Bernstein, M. Bishai, E. Blucher, D. B. Cline, M. V. Diwan, *et al.*, “Report on the Depth
 8 Requirements for a Massive Detector at Homestake,” FERMILAB-TM-2424-E,
 9 BNL-81896-2008-IR, LBNL-1348E, arXiv:0907.4183 [hep-ex], 2009. Cited in
 10 Section 5.3.1 (pg.144).
- 11 192. V. Kudryavtsev *et al.*, “Cosmic rays and cosmogenics. report to the lbne collaboration.,”
 12 LBNE-doc-5904, 2012. Cited in Section 5.3.1 (pg.144).
- 13 193. K. Kobayashi *et al.*, **Super-Kamiokande Collaboration**, “Search for nucleon decay via
 14 modes favored by supersymmetric grand unification models in Super-Kamiokande-I,”
 15 *Phys.Rev.* **D72** (2005) 052007, arXiv:hep-ex/0502026 [hep-ex]. Cited in
 1 Section 5.3.2 (pg.146).
- 2 194. H. Gallagher, “Private communication.”. Cited in Section 5.3.2 (pg.148).
- 3 195. H.-T. Janka, “Explosion Mechanisms of Core-Collapse Supernovae,”
 4 *Ann.Rev.Nucl.Part.Sci.* **62** (2012) 407–451, arXiv:1206.2503 [astro-ph.SR]. Cited in
 5 Section 6.1 (pg.151).

- 6 196. T. Fischer, S. Whitehouse, A. Mezzacappa, F.-K. Thielemann, and M. Liebendorfer,
7 “Protoneutron star evolution and the neutrino driven wind in general relativistic neutrino
8 radiation hydrodynamics simulations,” *Astron.Astrophys.* **517** (2010) A80,
9 arXiv:0908.1871 [astro-ph.HE]. Cited in Section 6.1 (pg.152).
- 10 197. M. Wurm *et al.*, **LENA Collaboration** , “The next-generation liquid-scintillator neutrino
11 observatory LENA,” *Astropart.Phys.* **35** (2012) 685–732, arXiv:1104.5620
12 [astro-ph.IM]. Cited in Section 6.1 (pg.152).
- 13 198. H. Minakata, H. Nunokawa, R. Tomas, and J. W. Valle, “Parameter Degeneracy in
14 Flavor-Dependent Reconstruction of Supernova Neutrino Fluxes,” *JCAP* **0812** (2008) 006,
15 arXiv:0802.1489 [hep-ph]. Cited in Section 6.1 (pg.152).
- 16 199. I. Tamborra, B. Muller, L. Hudepohl, H.-T. Janka, and G. Raffelt, “High-resolution
1 supernova neutrino spectra represented by a simple fit,” *Phys.Rev.* **D86** (2012) 125031,
2 arXiv:1211.3920 [astro-ph.SR]. Cited in Section 6.1 (pg.152).
- 3 200. H. Duan, G. M. Fuller, and Y.-Z. Qian, “Collective neutrino flavor transformation in
4 supernovae,” *Phys.Rev.* **D74** (2006) 123004, arXiv:astro-ph/0511275 [astro-ph].
5 Cited in Section 6.1 (pg.152).
- 6 201. G. L. Fogli, E. Lisi, A. Marrone, and A. Mirizzi, “Collective neutrino flavor transitions in
7 supernovae and the role of trajectory averaging,” *JCAP* **0712** (2007) 010,
8 arXiv:0707.1998 [hep-ph]. Cited in Section 6.1 (pg.152).
- 9 202. G. G. Raffelt and A. Y. Smirnov, “Self-induced spectral splits in supernova neutrino
10 fluxes,” *Phys.Rev.* **D76** (2007) 081301, arXiv:0705.1830 [hep-ph]. Cited in
11 Section 6.1 (pg.152).
- 12 203. G. G. Raffelt and A. Y. Smirnov, “Adiabaticity and spectral splits in collective neutrino
13 transformations,” *Phys.Rev.* **D76** (2007) 125008, arXiv:0709.4641 [hep-ph]. Cited in
14 Section 6.1 (pg.152).
- 15 204. A. Esteban-Pretel, A. Mirizzi, S. Pastor, R. Tomas, G. Raffelt, *et al.*, “Role of dense matter
16 in collective supernova neutrino transformations,” *Phys.Rev.* **D78** (2008) 085012,
17 arXiv:0807.0659 [astro-ph]. Cited in Section 6.1 (pg.152).
- 18 205. H. Duan and J. P. Kneller, “Neutrino flavour transformation in supernovae,” *J.Phys.G* **G36**
19 (2009) 113201, arXiv:0904.0974 [astro-ph.HE]. Cited in Section 6.1 (pg.152).
- 20 206. B. Dasgupta, A. Dighe, G. G. Raffelt, and A. Y. Smirnov, “Multiple Spectral Splits of
21 Supernova Neutrinos,” *Phys.Rev.Lett.* **103** (2009) 051105, arXiv:0904.3542 [hep-ph].
22 Cited in Section 6.1 (pg.152).
- 23 207. H. Duan, G. M. Fuller, and Y.-Z. Qian, “Collective Neutrino Oscillations,”
24 *Ann.Rev.Nucl.Part.Sci.* **60** (2010) 569–594, arXiv:1001.2799 [hep-ph]. Cited in
25 Section 6.1 (pg.152).
- 26 208. H. Duan and A. Friedland, “Self-induced suppression of collective neutrino oscillations in
27 a supernova,” *Phys.Rev.Lett.* **106** (2011) 091101, arXiv:1006.2359 [hep-ph]. Cited in
28 Sections 6.1 (pg.152) and 6.2 (pg.155).

- 1 209. J. F. Cherry, J. Carlson, A. Friedland, G. M. Fuller, and A. Vlasenko, “Halo Modification
2 of a Supernova Neutronization Neutrino Burst,” *Phys. Rev.* **D87** (2013) 085037,
3 arXiv:1302.1159 [astro-ph.HE]. Cited in Section 6.1 (pg.153).
- 4 210. J. F. Beacom, R. Boyd, and A. Mezzacappa, “Black hole formation in core collapse
5 supernovae and time-of-flight measurements of the neutrino masses,” *Phys. Rev.* **D63**
6 (2001) 073011, arXiv:astro-ph/0010398 [astro-ph]. Cited in Section 6.1 (pg.153).
- 7 211. T. Fischer, S. C. Whitehouse, A. Mezzacappa, F. K. Thielemann, and M. Liebendorfer,
8 “The neutrino signal from protoneutron star accretion and black hole formation,”
9 arXiv:0809.5129 [astro-ph], 2008. Cited in Section 6.1 (pg.153).
- 10 212. R. C. Schirato and G. M. Fuller, “Connection between supernova shocks, flavor
11 transformation, and the neutrino signal,” LA-UR-02-3068, arXiv:astro-ph/0205390
12 [astro-ph], 2002. Cited in Section 6.1 (pg.153).
- 13 213. F. Hanke, A. Marek, B. Muller, and H.-T. Janka, “Is Strong SASI Activity the Key to
14 Successful Neutrino-Driven Supernova Explosions?,” *Astrophys.J.* **755** (2012) 138,
15 arXiv:1108.4355 [astro-ph.SR]. Cited in Section 6.1 (pg.153).
- 16 214. F. Hanke, B. Mueller, A. Wongwathanarat, A. Marek, and H.-T. Janka, “SASI Activity in
17 Three-Dimensional Neutrino-Hydrodynamics Simulations of Supernova Cores,”
18 *Astrophys.J.* **770** (2013) 66, arXiv:1303.6269 [astro-ph.SR]. Cited in
19 Section 6.1 (pg.153).
- 20 215. A. Friedland and A. Gruzinov, “Neutrino signatures of supernova turbulence,”
21 LA-UR-06-2202, arXiv:astro-ph/0607244 [astro-ph], 2006. Cited in
22 Section 6.1 (pg.153).
- 23 216. T. Lund and J. P. Kneller, “Combining collective, MSW, and turbulence effects in
24 supernova neutrino flavor evolution,” arXiv:1304.6372 [astro-ph.HE], 2013. Cited in
25 Section 6.1 (pg.153).
- 26 217. G. G. Raffelt, “Particle Physics from Stars,” *Ann. Rev. Nucl. Part. Sci.* **49** (1999) 163–216,
27 arXiv:hep-ph/9903472. Cited in Section 6.1 (pg.153).
- 28 218. A. Bueno, I. Gil Botella, and A. Rubbia, “Supernova neutrino detection in a liquid argon
29 TPC,” ICARUS-TM-03-02, arXiv:hep-ph/0307222 [hep-ph], 2003. Cited in
30 Section 6.1 (pg.153).
- 1 219. K. Scholberg *et al.*, “SNOWGLoBES: SuperNova Observatories with GLoBES.”
2 <http://www.phy.duke.edu/~schol/snowglobes>. Cited in Section 6.2 (pg.154).
- 3 220. E. D. Church, “LArSoft: A Software Package for Liquid Argon Time Projection Drift
4 Chambers,” arXiv:1311.6774 [physics.ins-det], 2013. Cited in
5 Sections 6.2 (pg.154) and A.1.1 (pg.213).
- 6 221. T. Totani, K. Sato, H. E. Dalhed, and J. R. Wilson, “Future detection of supernova neutrino
7 burst and explosion mechanism,” *Astrophys. J.* **496** (1998) 216–225,
8 arXiv:astro-ph/9710203. Cited in Section 6.2 (pg.155).
- 9 222. J. Gava, J. Kneller, C. Volpe, and G. C. McLaughlin, “A dynamical collective calculation
10 of supernova neutrino signals,” *Phys. Rev. Lett.* **103** (2009) 071101, arXiv:0902.0317
11 [hep-ph]. Cited in Section 6.2 (pg.155).

12. 223. L. Hudepohl, B. Muller, H.-T. Janka, A. Marek, and G. Raffelt, “Neutrino Signal of
13. Electron-Capture Supernovae from Core Collapse to Cooling,” *Phys.Rev.Lett.* **104** (2010)
1 251101, arXiv:0912.0260 [astro-ph.SR]. Cited in Section 6.2 (pg.155).
2. 224. A. Cherry, A. Friedland, and H. Duan, “Private communication.”.
3. 225. M. T. Keil, G. G. Raffelt, and H.-T. Janka, “Monte Carlo study of supernova neutrino
4 spectra formation,” *Astrophys.J.* **590** (2003) 971–991, arXiv:astro-ph/0208035
5 [astro-ph].
6. 226. E. Church *et al.*, “Muon-induced background for beam neutrinos at the surface,”
1 LBNE-doc-6232, October, 2012. Cited in Sections 6.3.1 (pg.158), A.4 (pg.229),
2 and A.4 (pg.230).
3. 227. Gehman, V. and Kadel, R, “Calculation of intrinsic and cosmogenic backgrounds in the
4 LBNE far detector for use in detection of supernova neutrinos,” LBNE-doc-8419, January,
5 2014. Cited in Section 6.3.2 (pg.159).
6. 228. J. H. Harley *et al.*, “Report No. 094 - Exposure of the Population in the United States and
7 Canada from Natural Background Radiation,” *National Council on Radiation Protection
and Measurements* (2014) . <http://www.ncrppublications.org/Reports/094>. Cited
8 in Section 6.3.3 (pg.160).
10. 229. L. Grandi, “Darkside-50: performance and results from the first atmospheric argon run,”
11 February, 2014. UCLA’s 11th Symposium on Sources and Detection of Dark Matter and
12 Dark Energy in the Universe. Cited in Section 6.3.3 (pg.160).
13. 230. D. Leonard, P. Grinberg, P. Weber, E. Baussan, Z. Djurcic, *et al.*, “Systematic study of
14 trace radioactive impurities in candidate construction materials for EXO-200,”
15 *Nucl.Instrum.Meth.* **A591** (2008) 490–509, arXiv:0709.4524 [physics.ins-det].
16 Cited in Section 6.3.3 (pg.160).
17. 231. D. Casper, “The Nuance neutrino physics simulation, and the future,”
18 *Nucl.Phys.Proc.Suppl.* **112** (2002) 161–170, arXiv:hep-ph/0208030 [hep-ph].
19. 232. G. Zeller, “Nuclear Effects in Water vs. Argon,” LBNE-doc-740, 2010.
20. 233. G. Zeller, “Expected Event Rates in the LBNE Near Detector,” LBNE-doc-783, 2010.
21. 234. S.R.Mishra, Apr, 1990. Review talk presented at Workshop on Hadron Structure Functions
22 and Parton Distributions, Fermilab. Cited in Section 7.1.1 (pg.164).
23. 235. R. Raja, “The Main injector particle production experiment (MIPP) at Fermilab,”
24 *Nucl.Instrum.Meth.* **A553** (2005) 225–230, arXiv:hep-ex/0501005 [hep-ex]. Cited in
25 Section 7.1.2 (pg.166).
26. 236. J. Formaggio and G. Zeller, “From eV to EeV: Neutrino Cross Sections Across Energy
27 Scales,” *Rev.Mod.Phys.* **84** (2012) 1307, arXiv:1305.7513 [hep-ex]. Cited in
28 Sections 7.1.3 (pg.166) and 7.4.4 (pg.182).
29. 237. W. J. Marciano and Z. Parsa, “Neutrino-Electron Scattering Theory,” *J. Phys.* **G29** (2003)
30 2629–2645, arXiv:hep-ph/0403168. Cited in Sections 7.1.4 (pg.167)
1 and 7.2.2 (pg.173).

- 2 238. S. Mishra, K. Bachmann, R. Bernstein, R. Blair, C. Foudas, *et al.*, “Measurement of
3 Inverse Muon Decay $\nu_\mu + e \rightarrow \mu^- + \nu_e$ at Fermilab Tevatron Energies 15-GeV -
4 600-GeV,” *Phys.Rev.Lett.* **63** (1989) 132–135. Cited in Section 7.1.5 (pg.167).
- 5 239. S. Mishra, K. Bachmann, R. Blair, C. Foudas, B. King, *et al.*, “Inverse Muon Decay,
6 $\nu_\mu e \rightarrow \mu^- \nu_e$, at the Fermilab Tevatron,” *Phys.Lett.* **B252** (1990) 170–176. Cited in
7 Section 7.1.5 (pg.167).
- 8 240. P. Vilain *et al.*, **CHARM-II Collaboration**, “A Precise measurement of the cross-section
9 of the inverse muon decay muon-neutrino + e- → mu- + electron-neutrino,” *Phys.Lett.*
10 **B364** (1995) 121–126. Cited in Section 7.1.5 (pg.167).
- 11 241. O. Samoylov *et al.*, **NOMAD**, “A Precision Measurement of Charm Dimuon Production
12 in Neutrino Interactions from the NOMAD Experiment,” *Nucl.Phys.* **B876** (2013)
13 339–375, arXiv:1308.4750 [hep-ex]. Cited in Sections 7.1.8 (pg.169),
1 7.2.1 (pg.172), and 7.4.4 (pg.183).
- 2 242. G. Zeller *et al.*, **NuTeV Collaboration**, “A Precise determination of electroweak
3 parameters in neutrino nucleon scattering,” *Phys.Rev.Lett.* **88** (2002) 091802,
4 arXiv:hep-ex/0110059 [hep-ex]. Cited in Section 7.2.1 (pg.170).
- 5 243. H. Abramowicz, R. Belusevic, A. Blondel, H. Blumer, P. Bockmann, *et al.*, **CDHS**
6 **Collaboration**, “A Precision Measurement of $\sin^{**2}\theta_W$ from Semileptonic
7 Neutrino Scattering,” *Phys.Rev.Lett.* **57** (1986) 298. Cited in Section 7.2.1 (pg.171).
- 8 244. J. Allaby *et al.*, **CHARM Collaboration**, “A Precise Determination of the Electroweak
9 Mixing Angle from Semileptonic Neutrino Scattering,” *Z.Phys.* **C36** (1987) 611. Cited in
1 Section 7.2.1 (pg.171).
- 1 245. P. Reutens, F. Merritt, D. MacFarlane, R. Messner, D. Novikoff, *et al.*, **CCFR**
2 **Collaboration**, “Measurement of $\sin^2 \theta_W$ and ρ in Deep Inelastic Neutrino - Nucleon
3 Scattering,” *Phys.Lett.* **B152** (1985) 404–410. Cited in Section 7.2.1 (pg.171).
- 4 246. S. Alekhin, S. A. Kulagin, and R. Petti, “Modeling lepton-nucleon inelastic scattering from
5 high to low momentum transfer,” *AIP Conf.Proc.* **967** (2007) 215–224, arXiv:0710.0124
6 [hep-ph]. Cited in Section 7.2.1 (pg.172).
- 7 247. S. Alekhin, S. A. Kulagin, and R. Petti, “Update of the global fit of PDFs including the
8 low-Q DIS data,” arXiv:0810.4893 [hep-ph], 2008. Cited in Section 7.2.1 (pg.172).
- 9 248. S. Alekhin, S. A. Kulagin, and R. Petti, “Determination of Strange Sea Distributions from
1 Neutrino-Nucleon Deep Inelastic Scattering,” *Phys.Lett.* **B675** (2009) 433–440,
2 arXiv:0812.4448 [hep-ph]. Cited in Section 7.2.1 (pg.172).
- 3 249. A. Arbuzov, D. Y. Bardin, and L. Kalinovskaya, “Radiative corrections to neutrino deep
4 inelastic scattering revisited,” *JHEP* **0506** (2005) 078, arXiv:hep-ph/0407203
5 [hep-ph]. Cited in Section 7.2.1 (pg.172).
- 6 250. S. A. Kulagin and R. Petti, “Global study of nuclear structure functions,” *Nucl.Phys.* **A765**
7 (2006) 126–187, arXiv:hep-ph/0412425 [hep-ph]. Cited in Section 7.2.1 (pg.172).
- 8 251. S. A. Kulagin and R. Petti, “Neutrino inelastic scattering off nuclei,” *Phys.Rev.* **D76** (2007)
9 094023, arXiv:hep-ph/0703033 [HEP-PH]. Cited in Sections 7.2.1 (pg.172),
10 7.4.2 (pg.181), and 7.6 (pg.186).

- 11 252. S. Kulagin and R. Petti, “Structure functions for light nuclei,” *Phys.Rev.* **C82** (2010)
12 054614, arXiv:1004.3062 [hep-ph]. Cited in Section 7.2.1 (pg.172).
- 13 253. P. Vilain *et al.*, **CHARM-II Collaboration**, “Precision measurement of electroweak
14 parameters from the scattering of muon-neutrinos on electrons,” *Phys.Lett.* **B335** (1994)
15 246–252. Cited in Section 7.2.2 (pg.173).
- 16 254. A. Czarnecki and W. J. Marciano, “Polarized Moller scattering asymmetries,”
17 *Int.J.Mod.Phys.* **A15** (2000) 2365–2376, arXiv:hep-ph/0003049 [hep-ph].
- 18 255. S. Bennett and C. Wieman, “Erratum: Measurement of the 6s → 7s Transition
19 Polarizability in Atomic Cesium and an Improved Test of the Standard Model [Phys. Rev.
20 Lett. 82, 2484 (1999)],” *Phys.Rev.Lett.* **82** (1999) 4153–4153.
- 21 256. W. Yao *et al.*, **Particle Data Group**, “Review of Particle Physics,” *J.Phys.* **G33** (2006)
1 1–1232.
- 2 257. P. Anthony *et al.*, **SLAC E158 Collaboration**, “Precision measurement of the weak
3 mixing angle in Moller scattering,” *Phys.Rev.Lett.* **95** (2005) 081601,
4 arXiv:hep-ex/0504049 [hep-ex].
- 5 258. J. H. Lee, “The Qweak: Precision measurement of the proton’s weak charge by parity
6 violating experiment,” *Few Body Syst.* **54** (2013) 129–134. Cited in Section 7.2.2 (pg.175).
- 7 259. Nuruzzaman, “Q-weak: First Direct Measurement of the Weak Charge of the Proton,”
arXiv:1312.6009 [nucl-ex], 2013. Cited in Section 7.2.2 (pg.175).
- 9 260. R. Jaffe and A. Manohar, “The G(1) Problem: Fact and Fantasy on the Spin of the Proton,”
1 Nucl.Phys. **B337** (1990) 509–546. Cited in Section 7.3 (pg.175).
- 2 261. R. D. Young, J. Roche, R. D. Carlini, and A. W. Thomas, “Extracting nucleon strange and
3 anapole form factors from world data,” *Phys.Rev.Lett.* **97** (2006) 102002,
4 arXiv:nucl-ex/0604010 [nucl-ex]. Cited in Sections 7.3.1 (pg.175)
5 and 7.3.1 (pg.176).
- 6 262. D. B. Leinweber, S. Boinepalli, I. Cloet, A. W. Thomas, A. G. Williams, *et al.*, “Precise
7 determination of the strangeness magnetic moment of the nucleon,” *Phys.Rev.Lett.* **94**
8 (2005) 212001, arXiv:hep-lat/0406002 [hep-lat]. Cited in Section 7.3.1 (pg.175).
- 9 263. L. Ahrens, S. Aronson, P. Connolly, B. Gibbard, M. Murtagh, *et al.*, “Measurement of
10 Neutrino - Proton and anti-neutrino - Proton Elastic Scattering,” *Phys.Rev.* **D35** (1987) 785.
11 Cited in Section 7.3.2 (pg.177).
- 12 264. G. Garvey, W. Louis, and D. White, “Determination of proton strange form-factors from
13 neutrino p elastic scattering,” *Phys.Rev.* **C48** (1993) 761–765. Cited in
14 Section 7.3.2 (pg.177).
- 15 265. W. Alberico, M. Barbaro, S. M. Bilenky, J. Caballero, C. Giunti, *et al.*, “Strange
16 form-factors of the proton: A New analysis of the neutrino (anti-neutrino) data of the
17 BNL-734 experiment,” *Nucl.Phys.* **A651** (1999) 277–286, arXiv:hep-ph/9812388
18 [hep-ph]. Cited in Section 7.3.2 (pg.177).
- 19 266. A. Aguilar-Arevalo *et al.*, **MiniBooNE Collaboration**, “Measurement of the Neutrino
20 Neutral-Current Elastic Differential Cross Section on Mineral Oil at $E_\nu \sim 1$ GeV,”

- 21 *Phys.Rev.* **D82** (2010) 092005, arXiv:1007.4730 [hep-ex]. Cited in
 22 Section 7.3.2 (pg.177).
- 23 267. L. Bugel *et al.*, **FINeSSE Collaboration**, “A Proposal for a near detector experiment on
 24 the booster neutrino beamline: FINeSSE: Fermilab intense neutrino scattering scintillator
 25 experiment,” FERMILAB-PROPOSAL-0937, arXiv:hep-ex/0402007 [hep-ex], 2004.
 26 Cited in Section 7.3.2 (pg.178).
- 27 268. W. Leung, P. Quintas, S. Mishra, F. Sciulli, C. Arroyo, *et al.*, “A Measurement of the
 28 Gross-Llewellyn-Smith sum rule from the CCFR x(F3) structure function,” *Phys.Lett.*
₁ **B317** (1993) 655–659. Cited in Section 7.4.1 (pg.180).
- 2 269. A. Bodek and A. Simon, “What Do Electron and Neutrino Experiments Tell Us About
 3 Nuclear Effects in the Deuteron,” *Z.Phys.* **C29** (1985) 231. Cited in
 4 Sections 7.4.3 (pg.181) and 7.4.3 (pg.182).
- 5 270. G. Jones *et al.*, **Birmingham-CERN-Imperial Coll.-MPI(Munich)-Oxford-University
 6 Coll. Collaboration**, “A Measurement of the Proton Structure Functions From Neutrino
 7 Hydrogen and Anti-neutrino Hydrogen Charged Current Interactions,” *Z.Phys.* **C44** (1989)
 8 379–384. Cited in Sections 7.4.3 (pg.181) and 7.4.3 (pg.182).
- 9 271. J. Berge, H. Burkhardt, F. Dydak, R. Hagelberg, M. Krasny, *et al.*, “A Measurement of
 10 Differential Cross-Sections and Nucleon Structure Functions in Charged Current Neutrino
 11 Interactions on Iron,” *Z.Phys.* **C49** (1991) 187–224.
- 12 272. D. Allasia *et al.*, **WA25 Collaboration**, “Measurement of the Neutron and Proton
 13 Structure Functions From Neutrino and Anti-neutrinos Scattering in Deuterium,”
₁₄ *Phys.Lett.* **B135** (1984) 231.
- 15 273. D. Allasia, C. Angelini, A. Baldini, L. Bertanza, A. Bigi, *et al.*, “Q**2 Dependence of the
 16 Proton and Neutron Structure Functions from Neutrino and anti-neutrinos Scattering in
 17 Deuterium,” *Z.Phys.* **C28** (1985) 321. Cited in Section 7.5 (pg.184).
- 18 274. U.-K. Yang *et al.*, **CCFR/NuTeV Collaboration**, “Measurements of F_2 and $xF_3^\nu - xF_3^{\bar{\nu}}$
 19 from CCFR ν_μ -Fe and $\bar{\nu}_\mu$ -Fe data in a physics model independent way,” *Phys.Rev.Lett.*
₂₀ **86** (2001) 2742–2745, arXiv:hep-ex/0009041 [hep-ex].
- 21 275. U.-K. Yang *et al.*, **CCFR/NuTeV Collaboration**, “Extraction of $R = \sigma(L) / \sigma(T)$
 22 from CCFR Fe-neutrino(muon) and Fe-anti-neutrino(muon) differential cross-sections,”
₂₃ *Phys.Rev.Lett.* **87** (2001) 251802, arXiv:hep-ex/0104040 [hep-ex].
- 24 276. M. Tzanov *et al.*, **NuTeV Collaboration**, “Precise measurement of neutrino and
 25 anti-neutrino differential cross sections,” *Phys.Rev.* **D74** (2006) 012008,
₂₆ arXiv:hep-ex/0509010 [hep-ex]. Cited in Section 7.4.4 (pg.183).
- 27 277. G. Onengut *et al.*, **CHORUS Collaboration**, “Measurement of nucleon structure
 28 functions in neutrino scattering,” *Phys.Lett.* **B632** (2006) 65–75.
- 1 278. R. Petti and O. Samoylov, “Charm dimuon production in neutrino-nucleon interactions in
 2 the NOMAD experiment,” *Phys.Part.Nucl.Lett.* **8** (2011) 755–761. Cited in
₃ Section 7.4.4 (pg.183).
- 4 279. T. Sekiguchi, “Neutrino facility and neutrino physics in J-PARC,” *PTEP* **2012** (2012)
₅ 02B005. Cited in Section 7.4.4 (pg.183).

- 6 280. J. Dudek, R. Ent, R. Essig, K. Kumar, C. Meyer, *et al.*, “Physics Opportunities with the 12
7 GeV Upgrade at Jefferson Lab,” *Eur.Phys.J. A***48** (2012) 187, arXiv:1208.1244
8 [hep-ex]. Cited in Section 7.4.4 (pg.183).
- 9 281. N. Mondal, “India-Based Neutrino Observatory (INO),” *Eur.Phys.J.Plus* **127** (2012) 106.
10 Cited in Section 7.6 (pg.185).
- 11 282. A. Butkevich, “Quasi-elastic neutrino charged-current scattering off medium-heavy nuclei:
12 40Ca and 40Ar,” *Phys.Rev. C***85** (2012) 065501, arXiv:1204.3160 [nucl-th]. Cited in
13 Section 7.6 (pg.186).
- 14 283. A. Butkevich and S. A. Kulagin, “Quasi-elastic neutrino charged-current scattering cross
15 sections on oxygen,” *Phys.Rev. C***76** (2007) 045502, arXiv:0705.1051 [nucl-th].
1 Cited in Section 7.6 (pg.186).
- 2 284. A. M. Ankowski and J. T. Sobczyk, “Construction of spectral functions for medium-mass
3 nuclei,” *Phys.Rev. C***77** (2008) 044311, arXiv:0711.2031 [nucl-th]. Cited in
4 Section 7.6 (pg.186).
- 5 285. T. Asaka and M. Shaposhnikov, “The nuMSM, dark matter and baryon asymmetry of the
6 universe,” *Phys.Lett. B***620** (2005) 17–26, arXiv:hep-ph/0505013 [hep-ph]. Cited in
7 Sections 7.7 (pg.187) and 7.7 (pg.188).
- 8 286. D. Gorbunov and M. Shaposhnikov, “How to find neutral leptons of the ν MSM?,” *JHEP*
9 **0710** (2007) 015, arXiv:0705.1729 [hep-ph]. Cited in Sections 7.7 (pg.187)
10 and 7.7 (pg.188).
- 11 287. A. Boyarsky, O. Ruchayskiy, and M. Shaposhnikov, “The Role of sterile neutrinos in
12 cosmology and astrophysics,” *Ann.Rev.Nucl.Part.Sci.* **59** (2009) 191–214,
13 arXiv:0901.0011 [hep-ph]. Cited in Section 7.7 (pg.187).
- 14 288. S. Dodelson and L. M. Widrow, “Sterile-neutrinos as dark matter,” *Phys.Rev.Lett.* **72**
15 (1994) 17–20, arXiv:hep-ph/9303287 [hep-ph]. Cited in Section 7.7 (pg.187).
- 16 289. A. Atre, T. Han, S. Pascoli, and B. Zhang, “The Search for Heavy Majorana Neutrinos,”
17 *JHEP* **0905** (2009) 030, arXiv:0901.3589 [hep-ph]. Cited in Sections 7.7 (pg.187)
18 and 7.7 (pg.188).
- 19 290. M. Shaposhnikov, “The nuMSM, leptonic asymmetries, and properties of singlet fermions,”
20 *JHEP* **0808** (2008) 008, arXiv:0804.4542 [hep-ph]. Cited in Section 7.7 (pg.187).
- 21 291. E. K. Akhmedov, V. Rubakov, and A. Y. Smirnov, “Baryogenesis via neutrino oscillations,”
22 *Phys.Rev.Lett.* **81** (1998) 1359–1362, arXiv:hep-ph/9803255 [hep-ph]. Cited in
23 Section 7.7 (pg.188).
- 24 292. A. M. Cooper-Sarkar *et al.*, **WA66 Collaboration**, “Search for Heavy Neutrino Decays in
25 the BEBC Beam Dump Experiment,” *Phys.Lett. B***160** (1985) 207. Cited in
26 Section 7.7 (pg.188).
- 27 293. F. Bergsma *et al.*, **CHARM Collaboration**, “A Search for Decays of Heavy Neutrinos in
28 the Mass Range 0.5-GeV to 2.8-GeV,” *Phys.Lett. B***166** (1986) 473. Cited in
1 Section 7.7 (pg.188).

- 2 294. A. Vaitaitis *et al.*, **NuTeV Collaboration, E815 Collaboration**, “Search for Neutral
3 Heavy Leptons in a High-Energy Neutrino Beam,” *Phys.Rev.Lett.* **83** (1999) 4943–4946,
4 arXiv:hep-ex/9908011 [hep-ex]. Cited in Section 7.7 (pg.188).
- 5 295. G. Bernardi, G. Carugno, J. Chauveau, F. Dicarlo, M. Dris, *et al.*, “Search for Neutrino
6 Decay,” *Phys.Lett.* **B166** (1986) 479. Cited in Section 7.7 (pg.188).
- 7 296. G. Bernardi, G. Carugno, J. Chauveau, F. Dicarlo, M. Dris, *et al.*, “Further Limits on
8 Heavy Neutrino Couplings,” *Phys.Lett.* **B203** (1988) 332. Cited in Section 7.7 (pg.188).
- 9 297. L. Canetti and M. Shaposhnikov, “Baryon Asymmetry of the Universe in the NuMSM,”
10 *JCAP* **1009** (2010) 001, arXiv:1006.0133 [hep-ph].
- 11 298. C. Kullenberg *et al.*, **NOMAD Collaboration**, “A Search for Single Photon Events in
12 Neutrino Interactions in NOMAD,” *Phys.Lett.* **B706** (2012) 268–275, arXiv:1111.3713
13 [hep-ex]. Cited in Section 7.7 (pg.190).
- 14 299. C. Volpe, N. Auerbach, G. Colo, T. Suzuki, and N. Van Giai, “Neutrino C-12 reactions and
15 the LSND and KARMEN experiments on neutrino oscillations,” *Phys. Atom. Nucl.* **64**
16 (2001) 1165–1168. Cited in Section 7.8 (pg.190).
- 17 300. M. Maltoni and T. Schwetz, “Sterile neutrino oscillations after first MiniBooNE results,”
18 *Phys.Rev.* **D76** (2007) 093005, arXiv:0705.0107 [hep-ph]. Cited in
19 Section 7.8 (pg.190).
- 20 301. P. Ade *et al.*, **Planck Collaboration**, “Planck 2013 results. XVI. Cosmological
21 parameters,” arXiv:1303.5076 [astro-ph.CO], 2013. Cited in Section 7.9 (pg.192).
- 22 302. C. Bennett *et al.*, **WMAP**, “Nine-Year Wilkinson Microwave Anisotropy Probe (WMAP)
23 Observations: Final Maps and Results,” *Astrophys.J.Suppl.* **208** (2013) 20,
24 arXiv:1212.5225 [astro-ph.CO]. Cited in Section 7.9 (pg.192).
- 25 303. B. Batell, M. Pospelov, and A. Ritz, “Exploring Portals to a Hidden Sector Through Fixed
26 Targets,” *Phys.Rev.* **D80** (2009) 095024, arXiv:0906.5614 [hep-ph]. Cited in
27 Section 7.9 (pg.193).
- 28 304. P. deNiverville, M. Pospelov, and A. Ritz, “Observing a light dark matter beam with
29 neutrino experiments,” *Phys.Rev.* **D84** (2011) 075020, arXiv:1107.4580 [hep-ph].
30 Cited in Section 7.9 (pg.193).
- 31 305. P. deNiverville, D. McKeen, and A. Ritz, “Signatures of sub-GeV dark matter beams at
32 neutrino experiments,” *Phys.Rev.* **D86** (2012) 035022, arXiv:1205.3499 [hep-ph].
33 Cited in Section 7.9 (pg.193).
- 1 306. R. Dharmapalan *et al.*, **MiniBooNE Collaboration**, “Low Mass WIMP Searches with a
2 Neutrino Experiment: A Proposal for Further MiniBooNE Running,”
3 FERMILAB-PROPOSAL-1032, arXiv:1211.2258 [hep-ex], 2012. Cited in
4 Section 7.9 (pg.193).
- 5 307. H. Bethe, “Energy production in stars,” *Phys.Rev.* **55** (1939) 434–456. Cited in
6 Section 8.1 (pg.195).
- 7 308. C. Weizsäcker, “Über Elementumwandlungen im Innern der Sterne II,” *Physik.Z.* **39** (1938)
1 633–646. Cited in Section 8.1 (pg.195).

- 2 309. J. N. Bahcall, A. M. Serenelli, and S. Basu, “New solar opacities, abundances,
3 helioseismology, and neutrino fluxes,” *Astrophys.J.* **621** (2005) L85–L88,
4 arXiv:astro-ph/0412440 [astro-ph]. Cited in Section 8.1 (pg.195).
- 5 310. S. Fukuda *et al.*, **Super-Kamiokande Collaboration**, “Solar B-8 and hep neutrino
6 measurements from 1258 days of Super-Kamiokande data,” *Phys.Rev.Lett.* **86** (2001)
7 5651–5655, arXiv:hep-ex/0103032 [hep-ex]. Cited in Section 8.1 (pg.195).
- 8 311. Q. Ahmad *et al.*, **SNO Collaboration**, “Measurement of the rate of nu/e + d -> p + p + e-
9 interactions produced by B-8 solar neutrinos at the Sudbury Neutrino Observatory,”
10 *Phys.Rev.Lett.* **87** (2001) 071301, arXiv:nucl-ex/0106015 [nucl-ex]. Cited in
11 Section 8.1 (pg.195).
- 12 312. G. Bellini, J. Benziger, D. Bick, S. Bonetti, G. Bonfini, *et al.*, “Precision measurement of
13 the 7Be solar neutrino interaction rate in Borexino,” *Phys.Rev.Lett.* **107** (2011) 141302,
1 arXiv:1104.1816 [hep-ex]. Cited in Section 8.1 (pg.197).
- 2 313. C. Kraus, **SNO+ Collaboration**, “SNO with liquid scintillator: SNO+,” *Prog. Part. Nucl.
3 Phys.* **57** (2006) 150–152. Cited in Section 8.1 (pg.197).
- 4 314. H. Sekiya, **Super-Kamiokande Collaboration**, “Solar neutrino analysis of
5 Super-Kamiokande,” arXiv:1307.3686, 2013. Cited in Section 8.1 (pg.197).
- 1 315. A. Guglielmi, **ICARUS Collaboration**, “Status and early events from ICARUS T600,”
2 *Nucl.Phys B (Proc. Suppl.)* **229-232** (2012) 342–346. Cited in Section 8.1 (pg.198).
- 3 316. G. Bellini *et al.*, **Borexino Collaboration**, “First evidence of pep solar neutrinos by direct
4 detection in Borexino,” *Phys.Rev.Lett.* **108** (2012) 051302, arXiv:1110.3230 [hep-ex].
- 5 317. G. Bellini *et al.*, **Borexino Collaboration**, “Measurement of the solar 8B neutrino rate
6 with a liquid scintillator target and 3 MeV energy threshold in the Borexino detector,”
7 *Phys.Rev.* **D82** (2010) 033006, arXiv:0808.2868 [astro-ph].
- 8 318. A. Gando *et al.*, **KamLAND Collaboration**, “Reactor On-Off Antineutrino Measurement
9 with KamLAND,” arXiv:1303.4667 [hep-ex], 2013. Cited in Section 8.1 (pg.199).
- 10 319. J. Silk, K. A. Olive, and M. Srednicki, “The Photino, the Sun and High-Energy Neutrinos,”
11 *Phys.Rev.Lett.* **55** (1985) 257–259. Cited in Section 8.2 (pg.199).
- 12 320. M. Cirelli, N. Fornengo, T. Montaruli, I. A. Sokalski, A. Strumia, *et al.*, “Spectra of
13 neutrinos from dark matter annihilations,” *Nucl.Phys.* **B727** (2005) 99–138,
14 arXiv:hep-ph/0506298 [hep-ph]. Cited in Section 8.2 (pg.200).
- 15 321. J. LoSecco, J. Van der Velde, R. Bionta, G. Blewitt, C. Bratton, *et al.*, “Limits on the Flux
16 of Energetic Neutrinos from the Sun,” *Phys.Lett.* **B188** (1987) 388. Cited in
17 Section 8.2 (pg.200).
- 18 322. M. Aartsen *et al.*, **IceCube Collaboration**, “Search for dark matter annihilations in the
19 Sun with the 79-string IceCube detector,” *Phys.Rev.Lett.* **110** (2013) 131302,
20 arXiv:1212.4097 [astro-ph.HE]. Cited in Section 8.2 (pg.200).
- 21 323. M. Blennow, M. Carrigan, and E. F. Martinez, “Probing the Dark Matter mass and nature
22 with neutrinos,” *JCAP* **1306** (2013) 038, arXiv:1303.4530 [hep-ph]. Cited in
23 Section 8.2 (pg.200).

- 24 324. T. Totani, K. Sato, and Y. Yoshii, “Spectrum of the supernova relic neutrino background
25 and evolution of galaxies,” *Astrophys.J.* **460** (1996) 303–312, arXiv:astro-ph/9509130
26 [astro-ph]. Cited in Section 8.3 (pg.201).
- 1 325. K. Sato, T. Totani, and Y. Yoshii, “Spectrum of the supernova relic neutrino background
2 and evolution of galaxies,” 1997. Cited in Section 8.3 (pg.201).
- 3 326. D. Hartmann and S. Woosley, “The cosmic supernova neutrino background,”
4 *Astropart.Phys.* **7** (1997) 137–146. Cited in Section 8.3 (pg.201).
- 5 327. R. Malaney, “Evolution of the cosmic gas and the relic supernova neutrino background,”
6 *Astropart.Phys.* **7** (1997) 125–136, arXiv:astro-ph/9612012 [astro-ph]. Cited in
7 Section 8.3 (pg.201).
- 8 328. M. Kaplinghat, G. Steigman, and T. Walker, “The Supernova relic neutrino background,”
9 *Phys.Rev.* **D62** (2000) 043001, arXiv:astro-ph/9912391 [astro-ph]. Cited in
10 Section 8.3 (pg.201).
- 11 329. S. Ando, J. F. Beacom, and H. Yuksel, “Detection of neutrinos from supernovae in nearby
12 galaxies,” *Phys.Rev.Lett.* **95** (2005) 171101, arXiv:astro-ph/0503321 [astro-ph].
13 Cited in Section 8.3 (pg.201).
- 14 330. C. Lunardini, “Testing neutrino spectra formation in collapsing stars with the diffuse
15 supernova neutrino flux,” *Phys.Rev.* **D75** (2007) 073022, arXiv:astro-ph/0612701
16 [astro-ph]. Cited in Section 8.3 (pg.201).
- 17 331. M. Fukugita and M. Kawasaki, “Constraints on the star formation rate from supernova relic
18 neutrino observations,” *Mon.Not.Roy.Astron.Soc.* **340** (2003) L7,
19 arXiv:astro-ph/0204376 [astro-ph]. Cited in Section 8.3 (pg.201).
- 20 332. P. Vogel and J. F. Beacom, “Angular distribution of neutron inverse beta decay,
21 anti-neutrino(e) + $p \rightarrow e^+ + n$,” *Phys.Rev.* **D60** (1999) 053003, arXiv:hep-ph/9903554
22 [hep-ph]. Cited in Section 8.3 (pg.201).
- 23 333. A. Strumia and F. Vissani, “Precise quasielastic neutrino nucleon cross section,” *Phys. Lett.*
1 **B564** (2003) 42–54, arXiv:astro-ph/0302055. Cited in Section 8.3 (pg.201).
- 2 334. W. E. Ormand, P. M. Pizzochero, P. F. Bortignon, and R. A. Broglia, “Neutrino capture
3 cross-sections for Ar-40 and Beta decay of Ti-40,” *Phys. Lett.* **B345** (1995) 343–350,
4 arXiv:nucl-th/9405007. Cited in Section 8.3 (pg.201).
- 5 335. E. Kolbe, K. Langanke, G. Martinez-Pinedo, and P. Vogel, “Neutrino nucleus reactions and
6 nuclear structure,” *J. Phys.* **G29** (2003) 2569–2596, arXiv:nucl-th/0311022. Cited in
7 Section 8.3 (pg.201).
- 8 336. M. Sajjad Athar and S. K. Singh, “nu/e (anti-nu/e) - Ar-40 absorption cross sections for
9 supernova neutrinos,” *Phys. Lett.* **B591** (2004) 69–75. Cited in Section 8.3 (pg.201).
- 10 337. A. Cocco, A. Ereditato, G. Fiorillo, G. Mangano, and V. Pettorino, “Supernova relic
11 neutrinos in liquid argon detectors,” *JCAP* **0412** (2004) 002, arXiv:hep-ph/0408031
12 [hep-ph]. Cited in Section 8.3 (pg.202).
- 13 338. R. Abbasi *et al.*, **IceCube Collaboration**, “Search for Relativistic Magnetic Monopoles
4 with IceCube,” *Phys.Rev.* **D87** (2013) 022001, arXiv:1208.4861 [astro-ph.HE]. Cited
5 in Section 8.4 (pg.203).

- 6 339. M. Aartsen *et al.*, **IceCube Collaboration**, “The IceCube Neutrino Observatory Part IV:
7 Searches for Dark Matter and Exotic Particles,” arXiv:1309.7007 [astro-ph.HE],
8 2013. Cited in Section 8.4 (pg.203).
- 9 340. K. Ueno *et al.*, **Super-Kamiokande Collaboration**, “Search for GUT Monopoles at
10 Super-Kamiokande,” *Astropart.Phys.* **36** (2012) 131–136, arXiv:1203.0940 [hep-ex].
11 Cited in Section 8.4 (pg.203).
- 12 341. M. Aartsen *et al.*, **IceCube Collaboration**, “Search for non-relativistic Magnetic
13 Monopoles with IceCube,” arXiv:1402.3460 [astro-ph.CO], 2014. Cited in
14 Section 8.4 (pg.203).
- 15 342. M. Ambrosio *et al.*, **MACRO Collaboration**, “Final results of magnetic monopole
16 searches with the MACRO experiment,” *Eur.Phys.J.* **C25** (2002) 511–522,
17 arXiv:hep-ex/0207020 [hep-ex]. Cited in Section 8.4 (pg.203).
- 18 343. R. Mohapatra, “Neutron-Anti-Neutron Oscillation: Theory and Phenomenology,” *J.Phys.*
19 **G36** (2009) 104006, arXiv:0902.0834 [hep-ph]. Cited in Section 8.5 (pg.204).
- 20 344. The United States Department of Energy, “Program and Project Management for the
21 Acquisition of Capital Assets,” DOE, DOE O 413.3B, November, 2010. Cited in
22 Section 9.1 (pg.206).
- 23 345. J. Strait, R. Wilson, and V. Papadimitriou, “LBNE Presentations to P5,” LBNE-doc-8694,
24 November, 2013. Cited in Section 9.1 (pg.207).
- 25 346. S. Bilenky and C. Giunti, “Neutrinoless double-beta decay: A brief review,” *Mod.Phys.Lett.*
1 A27 (2012) 1230015, arXiv:1203.5250 [hep-ph]. Cited in Section 9.2 (pg.209).
- 2 347. **LBNE Project Management Team**, “LBNE Conceptual Design Report: The LBNE
3 Water Cherenkov Detector,” LBNE-doc-5118, 2012. Cited in Section 9.3 (pg.210).
- 4 348. J. Hewett, H. Weerts, K. Babu, J. Butler, B. Casey, *et al.*, “Planning the Future of U.S.
5 Particle Physics (Snowmass 2013): Chapter 2: Intensity Frontier,”
6 FERMILAB-CONF-14-019-CH02, arXiv:1401.6077 [hep-ex], 2014. Cited in
7 Section 9.4.1 (pg.210).
- 8 349. C. Green, J. Kowalkowski, M. Paterno, M. Fischler, L. Garren, *et al.*, “The art framework,”
9 *J.Phys.Conf.Ser.* **396** (2012) 022020. Cited in Section A.1.1 (pg.213).
- 10 350. T. Katori, **MicroBooNE Collaboration**, “MicroBooNE, A Liquid Argon Time Projection
11 Chamber (LArTPC) Neutrino Experiment,” *AIP Conf.Proc.* **1405** (2011) 250–255,
12 arXiv:1107.5112 [hep-ex]. Cited in Sections A.1.1 (pg.213) and A.3 (pg.221).
- 13 351. M. Soderberg, **ArgoNeuT Collaboration**, “ArgoNeuT: A Liquid Argon Time Projection
14 Chamber Test in the NuMI Beamline,” FERMILAB-CONF-09-516-E, arXiv:0910.3433
15 [physics.ins-det], 2009. Cited in Section A.1.1 (pg.213).
- 16 352. D. Huffman, “A Method for the Construction of Minimum-Redundancy Codes,” in
17 *Proceedings of the IRE*. 1952. Cited in Section A.1.1 (pg.215).
- 18 353. M. Szydagis, N. Barry, K. Kazkaz, J. Mock, D. Stolp, *et al.*, “NEST: A Comprehensive
19 Model for Scintillation Yield in Liquid Xenon,” *JINST* **6** (2011) P10002,
20 arXiv:1106.1613 [physics.ins-det]. Cited in Section A.1.1 (pg.215).

- 21 354. C. Hagman, D. Lange, J. Verbeke, and D. Wright, “Cosmic-ray Shower Library (CRY),”
22 Lawrence Livermore National Laboratory, UCRL-TM-229453, March, 2012.
23 http://nuclear.llnl.gov/simulation/doc_cry_v1.7/cry.pdf. Cited in
24 Section A.1.1 (pg.216).
- 25 355. R. P. Sandhir, S. Muhuri, and T. Nayak, “Dynamic Fuzzy c-Means (dFCM) Clustering and
26 its Application to Calorimetric Data Reconstruction in High Energy Physics,”
27 *Nucl.Instrum.Meth.* **A681** (2012) 34–43, arXiv:1204.3459 [nucl-ex]. Cited in
28 Section A.2 (pg.218).
- 1 356. R. E. Kalman, “A new approach to linear filtering and prediction problems,” *Transactions*
2 *of the ASME-Journal of Basic Engineering* **82** no. Series D, (1960) 35–45. Cited in
3 Section A.2 (pg.218).
- 4 357. J. Marshall and M. Thomson, “The Pandora software development kit for particle flow
5 calorimetry,” *J.Phys.Conf.Ser.* **396** (2012) 022034. Cited in Section A.2 (pg.219).
- 6 358. A. Accardi, J. Albacete, M. Anselmino, N. Armesto, E. Aschenauer, *et al.*, “Electron Ion
7 Collider: The Next QCD Frontier - Understanding the glue that binds us all,”
8 BNL-98815-2012-JA, JLAB-PHY-12-1652, arXiv:1212.1701 [nucl-ex], 2012. Cited
9 in Sections B (pg.233) and B (pg.235).